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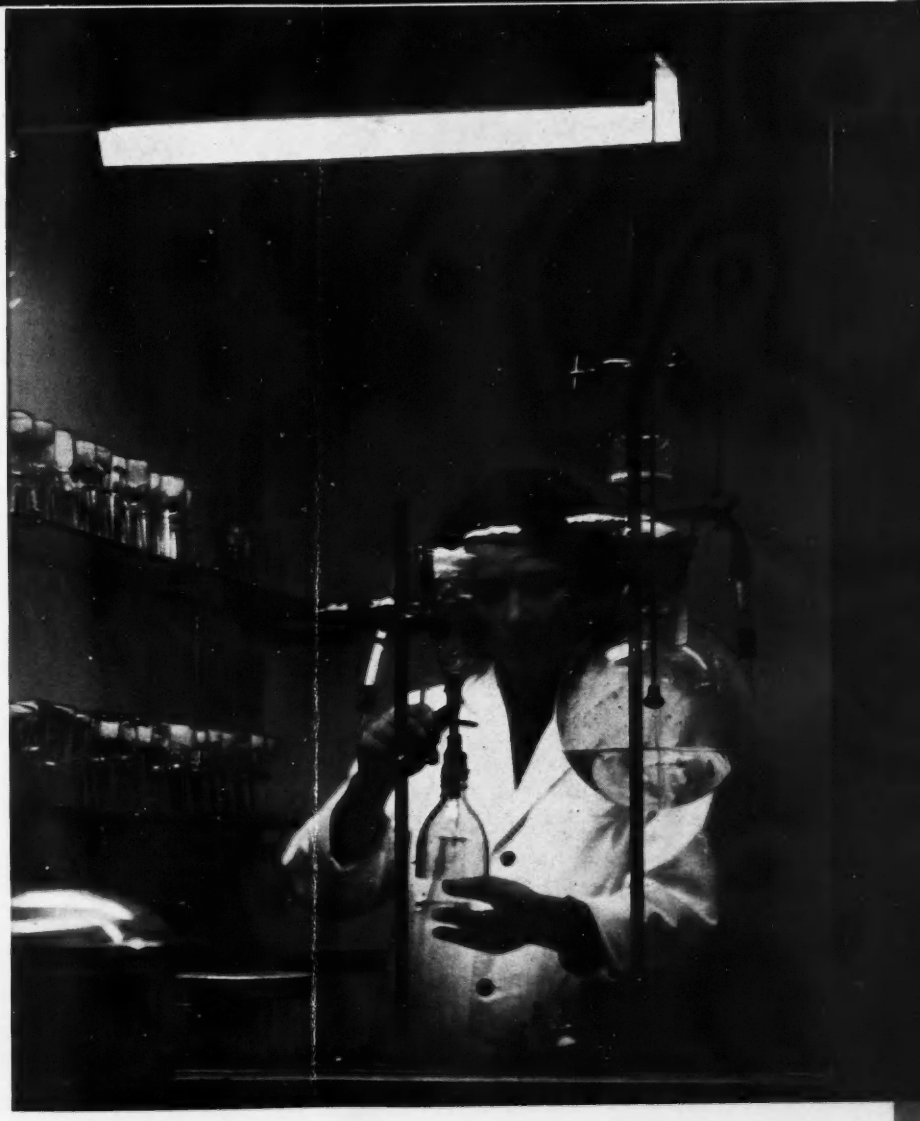

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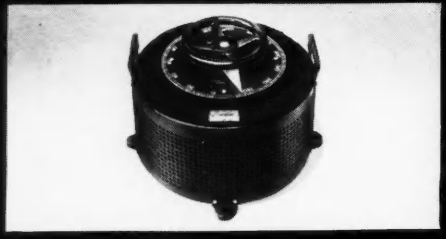

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G. Belliboni, B. Sechi and G. T. Zorn of the University of Padua have recently observed the first complete $\tau$-meson event. This was recorded in Ilford Nuclear Research Emulsion, Type G5, during the 1953 Cosmic Ray Expedition to Sardinia.

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The aim of the Expedition to Sardinia, in which the universities of nine European countries participated during June and July 1953, was to fly Ilford Nuclear Research Emulsion, Type G5, to altitudes greater than 80,000 feet for further research on cosmic radiation. The emulsion units were blocks measuring 20 cm. × 15 cm. × 2·4 cm., each assembled from 40 sheets, 600$\mu$ thick without support. The choice of Ilford G5 emulsion for this important work is a further tribute to its remarkable consistency and excellent performance, qualities which it shares with all Ilford sensitised materials, whether designed for scientific purposes, for radiography, or for general photography.

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THE MAGAZINE OF SCIENTIFIC PROGRESS

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## THE PROGRESS OF SCIENCE

### SIDELIGHTS ON THE SCIENTIFIC CIVIL SERVICE

The Scientific Civil Service is now a much bigger affair than it was before the last war, and it certainly offers better career prospects to young scientists than it did in 1939. Their keenness to become Government scientists is indicated by the fierceness of the competition for places in certain sciences. For example, Dr. C. P. Snow, the ex-editor of DISCOVERY, who is now one of the Civil Service Commissioners, has stated that they receive hundreds of applications from biologists when perhaps there are only fifteen vacancies to be filled. Again, in 1953, at least a hundred chemists with first-class honours and excellent research experience applied for posts in the Scientific Officer grade of the Civil Service, a figure far in excess of the number of vacancies that existed.

The Royal Commission on the Civil Service have been looking into certain aspects of the scientific side of the service. The starting point for their investigation was the memorandum dealing with scientific, engineering, architectural and allied professional and technical classes submitted by the Civil Service Commissioners. This document says that the difficulty of securing new recruits to the scientific classes of the Civil Service varies very much from science to science, and the Commissioners express the opinion that the highest quality scientists still make their career in fundamental research at the universities. Of the scientists just below the highest rank, the Civil Service "*recruits its fair share, and possibly more than its fair share*". Prior to 1953 the Civil Service Commissioners considered they were at a disadvantage compared with industrial employers because the starting salary in all grades of Government service was perceptibly lower than the starting salaries in industry. The Commissioners say that now "the starting salaries for most successful candidates are probably at least as attractive as they can expect in industry". They feel, however, that industry can still outbid the Civil Service so far as exceptional scientists are concerned.

The Commissioners express great faith in the scheme of Research Fellowships which was started by the Atomic Energy Research Establishment at Harwell and by T.R.E. at Malvern, and which has now been applied by other scientific branches of the Civil Service. According to the Commissioners' memorandum, this scheme has proved remarkably successful in attracting applicants of very high class. In effect, these Fellowships are really short-term engagements at salaries about the same as those paid to the Scientific Officer class but not tied to a rigid age-scale; that means that a brilliant young candidate can be paid at the maximum Fellowship rate. They attract men who are quite glad to do three years in the Government Service before settling into their final career. In most cases their final career will be in the universities, but the Government Service will retain a useful proportion. The Royal Commission was told that about 30 Research Fellows are appointed a year. 1953 was the first year that the scheme was in full operation. At Harwell there have been such fellowships for four or five years, and about 40% of these Fellows have been retained. One statement made before the Royal Commission revealed that under this scheme it is possible to pay a man of 23 or 24 £800. For the senior Research Fellowships there are no age limits.

The Commissioners' memorandum states that "the educational levels of recruitment to the scientific, experimental and assistant scientific classes are in general comparable with those of the administrative, executive and clerical classes respectively". This, we feel, was a very rash remark to make for the true facts appear to contradict it very forcibly. It has indeed been questioned by the Royal Commission, one of whose members quoted a statement by the Commissioners to the effect that one-third of the open competition entrants to the assistant experimental officer and experimental officer grades have degrees and suggested that these scientific civil servants represented a rather higher educational calibre than the executive class. He suggested that as only 5% of entrants to the executive class have degrees, then the entrants for these particular scientific grades could be regarded as a superior type educationally. To this the First Commissioner's reply on behalf of the Civil Service Commissioners was: "I have no comment"—but he made no attempt to

justify the dubious statement in the memorandum which prompted the Royal Commission's questions.

It is only fair to mention that a more concrete answer was given when Dr. Snow was asked by the Royal Commission about the demand for specific categories of scientists. With regard to physics, he made a very definite statement to the effect that any physicist of first- or second-class honours ability who has any sort of aptitude for research is taken into the Civil Service. He added that the physicists most needed are largely electronic physicists and certain types of classical physicists.

## 'QUEEN SUBSTANCE': THE BASIS OF THE BEES' SOCIAL INSTINCT

The Bee Department at Rothamsted Experimental Station is one of the most active centres of bee research in the world. Only two months ago we published a "Progress of Science" note dealing with a new book written by one of the bee experts at Rothamsted, Ronald Ribbands. Now another important new book has come from the same stable (or should we say, same apiary?). This, the latest volume in the "New Naturalist" Series, is entitled *The World of the Honeybee* (London, Collins, 226 pp., one guinea).

Its author is Dr. Colin G. Butler, who is head of Rothamsted's Bee Department and whose contributions to DISCOVERY will still be fresh in our readers' memories. Dr. Butler's new book, which is illustrated by some of the finest bee photographs ever published, is full of up-to-the-minute information and one discovery he mentions we had not come across before. This is Dr. Butler's own brand-new discovery of what he calls 'queen substance'. A few days after we received our review copy of *The World of the Honeybee* the latest annual report of Rothamsted* reached us, and we find that this contains a concise note about the 'queen substance' discovery. We can hardly do better than quote this note *in extenso*, for it is of course in Dr. Butler's own words.

Dr. Butler has shown that queen honeybees secrete on all parts of their bodies a substance (which he calls the 'queen substance') which the household bees of their colonies urgently seek. This substance is obtained by young worker bees, who happen to be near to the queen at any given time, by licking her body. Many of the bees that have just obtained a supply directly from the queen move rapidly over the combs offering food which contains 'queen substance' to other members of their colony. In this way 'queen substance' becomes widely shared amongst the members of a colony. As long as worker bees obtain sufficient 'queen substance' they remain inhibited from building emergency or supersedure queen cells, and from tolerating the presence of eggs or larvae in swarm queen cell cups (or artificial queen cell cups).

The 'queen substance' of virgin queens appears to differ from that of mated, laying queens, but it is probable that all virgin queens produce one kind of substance and that all mated queens produce another kind. The results of experiments indicate that it is appreciation of the difference between the 'queen substances' of virgin and mated, laying queens, rather than any difference in their behaviour, which enables worker honeybees to distinguish between them.

It seems probable that the readily demonstrable craving of workers for 'queen substance' is one of the most important factors, if not the most important, in the maintenance of colony cohesion, not only in honeybees but also in the ants and termites. It is also very likely that it plays an important part in swarming; a temporary shortage of supply or, more probably, a breakdown in its distribution, leading to the toleration of eggs and larvae in queen cell cups.

* *Report of the Rothamsted Experimental Station for 1953*, 227 pp., 7*s*. 6*d*. post free, from Rothamsted, Harpenden, Herts.

## MYXOMATOSIS: A PROGRESS REPORT FROM AUSTRALIA

Whereas Europe is watching the spread of myxomatosis among the rabbit population with very mixed feelings, the Australians seem to have no doubts whatsoever about the efficacy of their campaign of extermination based on the virus they originally obtained from the Rockefeller Institute in America. The Commonwealth Scientific and Industrial Research Organisation has just produced a statement which surveys the situation that exists in Australia today. This statement summarises the latest reports from field officers of the C.S.I.R.O. Wildlife Survey Section, and the facts it contains justify the Australians in their present view that the attempt to rid their continent of rabbits has been well worth while.

This document looks into the question of whether Australian rabbits are developing an immunity to the virus or not. The facts appear to be as follows. There is good evidence that, after two to three years of self-perpetuation in the field, the virus has 'slipped back' in virulence from its original level at which it killed 99% or more of infected rabbits. A kill of 90 to 95% of infected animals seems to have been the rule during the 1952–3 outbreaks. This meant that the surviving populations often had a high proportion of recovered animals, which are immune to subsequent infection. Their offspring, however, are not immune or resistant to the disease. This has been well demonstrated this season by the very satisfactory kills that have been recorded in those areas where mosquitoes have been in adequate numbers to produce a high infection rate. In many such areas the susceptible new generation seems to have been virtually wiped out by outbreaks of the disease originating from fresh inoculations.

It is the opinion of Prof. Frank Fenner, the virus expert of the Australian National University, that the virus has 'settled down' in Australia to a virulence approximating to that of the 'wild' strain of myxomatosis virus found in Brazil, the original home of this rabbit disease. He ranks the 'standard' strain of virus used to initiate the Australian myxomatosis epidemic as a laboratory variant of the 'wild' Brazilian strain, with an artificially enhanced virulence.

The C.S.I.R.O. statement says that if Prof. Fenner is correct in saying that the virus has reverted to what may be considered the natural state, it means that the virus will tend to stabilise in the field at a level of virulence that will kill at least 90% of infected rabbits, and not deteriorate progressively over the years, as was once feared to be

likely. The statement goes on to point out that an infection with a case mortality rate of 90 to 95% is still highly lethal, as diseases go; but from the point of view of its controlling effect it is a very different thing from one killing over 99%. A virus killing over 99% leaves only 5 to 10 survivors among one thousand infected rabbits; a virus killing between 90 to 95% leaves between 50 and 100 survivors per thousand—a very dangerous breeding residue, capable of giving rise to a substantial infestation before the next summer's epidemics cut the population back once more. In these circumstances the weather becomes a decisive factor because the prevalence or otherwise of insect vectors of myxomatosis depends upon it. The C.S.I.R.O. scientists are coming to the conclusion that the spread of the disease is most favoured by adequate rainfall in the late winter and spring. This condition applied in the second season (1951–2) of the campaign, when there was good winter and spring rain. The creeks in the hilly and undulating grazing country ran into the warm weather, and then dried up into a series of holes ideal for the breeding of the mosquito vector (*Anopheles annulipes*). The upshot was a tremendous extension of the disease, which benefited the whole of central Victoria and much of eastern Victoria. Climatic conditions were even more favourable in 1952–3, and there was an abundance of insect vectors, including a Simulid fly, which apparently plays a useful part in spreading the infection.

The 1953–4 summer saw an entirely different situation. There had been little rain in the winter and spring, so that the hill creeks which provide the mosquito with breeding grounds dried out. The result was a lack of mosquitoes, and myxomatosis became less prevalent simply because it lacked an effective population of insect carriers.

On the whole it looks as though the kind of season which provides abundant food for the rabbits is just the kind of season which makes for a big population of the right species of mosquito to carry myxomatosis. The Australian scientists regard this as most encouraging, though they admit that it is very easy to envisage a year in which all the odds would favour the rabbit—a year, for instance, in which the rain was distributed in such a way as to produce green feed that encouraged rapid breeding of the rabbits, but failed to cause creeks to run and give surface water at the right time to produce a good and widespread population of vector insects.

What the ultimate benefit that myxomatosis will bring to Australia is still purely conjectural, but the short-term benefits appear to be real enough. In 1950 the rabbit was virtually beyond control over much of eastern Australia; that acute situation was swept away by the myxomatosis epidemic. Farming production in that region has been boosted to the tune of many millions of pounds. It gave hundreds, perhaps thousands, of landholders a free demonstration of what their land could produce when the pressure of the rabbit had been removed from it. This, to a generation that has never known a rabbit-free land and has come to accept the pest as almost inevitable, should do more than any verbal exhortation to convince property owners that the labour and expense of intensive eradication measures are economically justified.

The Australians are not relying on myxomatosis alone. They recognise that the policy must be one of *total eradication*, since a residue of immune rabbits may remain after myxomatosis has done its work and that residue might build up into a large population of rabbits immune to myxomatosis. For that reason the Australians are mopping up the rabbits that survive the attack of the virus, and they are vigorously exploiting all the standard methods for destroying rabbits.

It may be that we in Britain could take advantage of the myxomatosis epidemic now raging through our countryside. If we are to derive any real and permanent benefit from this epidemic we shall almost certainly have to adopt the Australians' policy of total eradication. At present there are hardly any grounds for believing that this no-quarter-for-the-rabbits policy would meet with unanimous acceptance in Britain, and it is not altogether surprising that there is a conflict of opinion on this question not only within the farming community but also within the Ministry of Agriculture. At present there is plenty of controversy but no finality as to what our policy ought to be. Some bolder spirits have taken the plunge by publishing articles that visualise what Britain will look like after the rabbits have disappeared. This is an interesting line of ecological speculation, which was well worked out by H. N. Southern in *Country Life* ("If Rabbits should Disappear", April 8, 1954, p. 1024). But this type of speculation strikes us as somewhat premature. The rabbits' disappearance from the British landscape seems a very remote contingency and one which will not depend solely upon the rabbit and the myxomatosis virus. The trick of making rabbits disappear will certainly require a helping hand from human conjurers, and nobody knows for certain whether the trick that seems to be working in Australia will work in Britain, or whether it will get any applause if it is eventually made to work here.

## BRITISH EXPERIMENTS WITH COLOUR TELEVISION

In May the Marconi Wireless Telegraph Co. gave a series of demonstrations of colour television to members of the radio industry and of the technical and scientific press in London. The object of the demonstrations was to show the equivalent of the American 'compatible' colour system in terms of the British standard of 405 lines, 50 frames per second. (A compatible colour TV system is one which will enable the existing monochrome receivers to reproduce an acceptable picture from a colour transmission; the importance of compatibility has dominated the American approach to the problem of colour television.)

Although such compatibility is desirable, there are some who believe that the development of colour television should not be shackled by insisting upon compatibility; some experts think that the existence of the black-and-white receivers should be ignored by the design engineers, who should go all out for an entirely new colour system which would give the best possible colour picture regardless of how it would register on black-and-white sets.

A much more important problem than compatibility is that of economy of band-width in the already over-congested ether. In order to compress the colour signals into as short a frequency spectrum as possible, the American

system uses a variety of exceedingly ingenious circuits, the details of which have appeared in various technical papers. When translated in terms of the British standards, the band-width required for colour television is 5 megacycles per second, against 3 megacycles for the monochrome picture. One of the arguments put forward by the Marconi engineers was that an increase of channel spacing to $7\frac{1}{2}$ megacycles would enable a better picture to be produced.

In his remarks to the audience at the demonstration, Mr. L. H. Bedford, Head of Research at the Marconi Company, pointed out that the colour standards in this country, once set up, would be set for all time and that it was preferable to choose a system which was as far as possible free from the restrictions of band-width which had been imposed in the American system.

The channel spacing in the ultra-high frequency bands (designated IV and V) could be employed satisfactorily in band III, the ultra-high frequency band allocated to commercial television and certain B.B.C. stations.

The technical development of colour television was proceeding satisfactorily, but the commercial limitations still remained to be overcome: chief among these was the high cost of the receiver and display tube.

The apparatus demonstrated comprised an array of colour tubes mounted in experimental racks. Of these tubes, two were of the American 'dot screen' type and two were of the projection type using dichroic mirrors to reproduce the picture from the three primary colours. A special Marconi camera was used in the small studio adjoining the receiver-room and films were also shown from a Marconi film scanner.

The general effect from the studio shots was excellent, and a full range of colour tones was obtained. Some of the whites in the pictures took on a pinkish tinge, but this was a matter of adjustment, and it was particularly noted that no alteration of the controls of the receivers was required during the whole of the demonstration. At the conclusion, the camera was pointed at the passing traffic in the Strand, and the colours of the posters and passing buses were strikingly reproduced.

It is as well to point out that the demonstration was a purely experimental one, intended to show the present state of colour television development by the Marconi Company, and that it does not herald the introduction of colour transmissions in Britain. In such a topical subject as colour television it is more than usually necessary to maintain a balanced attitude in reporting developments, as ill-founded claims may affect the sales of television receivers throughout the country. Those who remember the extravagant claims that were made when television was first introduced in 1927 will not be misled by similar claims for colour television in 1954. That it will come ultimately is certain; that it will take a long time in coming is almost equally certain, and in the meantime there is the nightly entertainment of the black-and-white picture.

## ENERGY IN THE FUTURE

The hydrogen bomb and other new weapons look particularly terrifying in the present context of international politics, for the world that has scarcely emerged from the shadows of one World War is still preoccupied with fears of another global war, with all its attendant atomic horrors. The threat of atomic warfare which became a reality in 1945 is something which can never be completely neutralised, and this threat will continue so long as men remain capable of making atomic bombs and of going to war. Moreover, in the words of Air Chief Marshal Sir Philip Joubert, "The control by convention of these weapons would by itself solve nothing. In the event of war they might still be used."

But this kind of situation has arisen before in connexion with other military weapons, and men will doubtless repeat the process of finding out how to live fruitful lives in spite of the ingenious weapons of destruction which they know exist, or which they know could be brought into existence in event of war. The present preoccupation with fears of atomic warfare is bound to evaporate sooner or later, and mankind will then be able to concentrate on some of the really big problems which will have to be solved if future generations are to be able to maintain any degree of civilised existence. For example, the problems which are being generated by the rapid increase in world population are tremendous problems, and their solution will call for scientific and technological efforts far greater than those which harnessed uranium fission to weapon production. Vital indeed are these problems, for fundamentally they are problems of survival.

In Britain it is usually the House of Lords rather than the Commons which takes the lead in broaching such big issues, and one can generally count upon the Lords expressing some interesting and expert opinions on such matters. On April 28 there was a debate on 'World Population and Resources' which was initiated by Lord Samuel. The peers had plenty of interesting things to say about food production and the urgent need to increase it. Equally pressing, however, are the problems of finding sufficient fuel and power to meet the world's increasing demands, and in this connexion we would have wished that someone like Lord Cherwell could have discussed world fuel and power resources. Some useful briefs on this subject are available for consultation by anyone who cares to take it up. For instance, a good deal of data on this subject was collected by Prof. F. E. Simon and five other authors into a set of six papers on different aspects of energy issued by Unesco in 1950, and an invaluable source of information is the proceedings of the various World Power Conferences* (published in this country by Lund Humphries & Co. Ltd.). We would recommend to anyone interested in this subject the report which Palmer Putnam prepared for the U.S. Atomic Energy Commission and which is now available in book form.†

In this report Mr. Putnam estimates the maximum plausible demands for energy during the next fifty to one hundred years, compared with the ability of nuclear fuels and all non-nuclear sources of energy to meet these demands at low cost. A forecast of this kind is a difficult job because first one has to forecast the future growth of populations. Here Mr. Putnam establishes his premises by studying

* The essence of Prof. Simon's Unesco report was published in article form in DISCOVERY (April and May issues, 1952).

† *Energy in the Future* by Palmer Putnam (London, Macmillan, 1954, 556 pp., 90*s*.).

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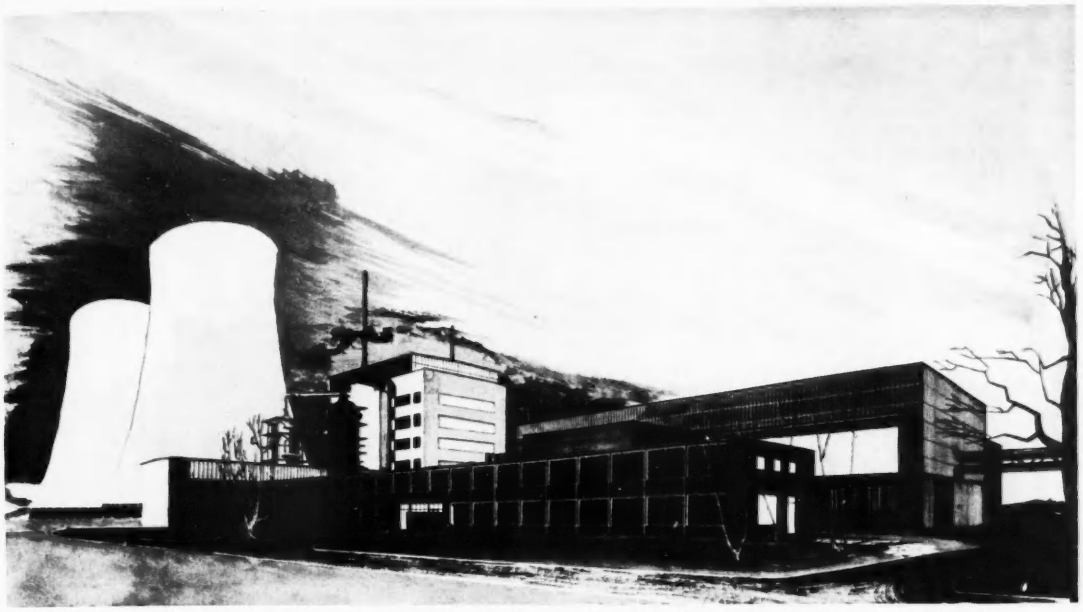


An architect's sketch showing how the Calder Hall atomic power station, which is being built close to the Windscale plutonium factory in Cumberland, will look when it is completed. Heat generated in the graphite-moderated uranium reactors will be conveyed to the steam-generating unit by carbon dioxide under pressure; the steam will power conventional turbo-alternators. The steam-raising plant, which will include eight steel towers each 80 ft. high suggestive of an oil refinery rather than a power station, is being built by Babcock & Wilcox; the turbo-alternator plant is being supplied by C. & A. Parsons Co. Ltd. The main contractors of the Calder Hall power station are Taylor Woodrow. (*Ministry of Works picture*)

population trends. He found that the population of China and the West passed through a minimum in the seventh or eighth centuries. Around A.D. 1600 there was an 'explosion' in population, again both in China and the West; why both should have followed the same pattern at the same time is not understood.

The first 'known' doubling of world population took about 950 years; the second 200 years, the third (ending in 1950) 100 years. At present growth rates, world population will double again in 85 years, reaching 4·6 thousand million by A.D. 2035. (Since Mr. Putnam wrote his report, the United Nations have confirmed this general picture but revised the rate of growth he assumed, 9 per thousand, to 11 per thousand.) If these populations are realised they cannot be based upon subsistence farming—a system which does not feed many non-farmers—but on a transition to an industrial-urban-farm pattern of life. It is this transition which entails increased production of energy and is therefore the basis of inquiry.

The study of American energy sources and consumptions gives some surprising results. In the U.S., half the coal ever consumed has been burnt since 1920, and half the oil and gas since 1940. Coal did not pass wood until 1890, oil and gas not until 1920. Wood is still nearly five times as important as water power. Throughout the world more energy was obtained from farm wastes than from all the fluid fuels until 1940.

If the pattern of energy consumption in one or two countries is looked at, the picture is again unexpected. The energy consumed per head is almost unchanged over the years. The U.S. averaged 220 million B.Th.U. per head in 1945 against 205 million in 1918. In Britain, the 1917 peak of 150 million B.Th.U. per head was not much higher than that of 1885, and it is now down to 130 million. On the other hand, the efficiency of use in the U.S. has increased $2\frac{1}{2}$ times, and in Britain nearly 3 times. This increase in the energy available cannot be repeated to anything like the same degree, since it has come from improvements in thermal and thermodynamic efficiencies to the point where returns are marginal only. *Somewhere or other increased available energy to meet an annual growth rate per head of around 3% has to be found.*

Based on these figures, the cumulative demand for energy can be matched against reserves, and this is the point Mr. Putnam looked for. When will our capital of fossil fuels—i.e. coal and oil—have been eaten up to the point where nuclear energy could compete on a cost basis? He takes a new unit of heat for ease of reckoning as $Q$, equal to $10^{18}$ B.Th.U.—i.e. a million, million million B.Th.U. In terms that can be grasped and are not just astronomical, one $Q$ is equivalent to 38,000 million tons of coal. Now in the first eighteen and a half centuries after Christ the total energy intake in the world is reckoned to have been between 6 and 9$Q$. In the next 100 years bringing us up to 1950, nearly half as much was burned up in addition—about 4$Q$. If the rate of growth in demand does not increase but stabilises at 3%, a further 10$Q$ will be required by A.D. 2000 and 70$Q$ by A.D. 2050. Estimates of coal

reserves show that only one-tenth of the gross deposits are likely to be extracted at any economical figure; if this is taken as twice 1950 costs, the world total is 32*Q*, of which 16*Q* are in China and the U.S.S.R. Oil reserves amount to 5·6*Q*, with shale and tar sands an uncertain 3·7*Q*. After allowing for conversion of solid fuels to liquid when the oil deposits work out and therefore for a loss in synthesis, world resources come out at 27*Q*, of which 4*Q* are in the U.S.

The sum adds up to one conclusion only—that the U.S. has enough fossil fuel to last until A.D. 2000. Living off 'income' and not 'capital' would postpone this, but it would require a colossal programme of afforestation which might yield 0·4*Q* in the next 50 years. The continued use of farm wastes could give 0·5*Q*, and a five-fold increase in water power 0·2*Q*. The use of solar energy collectors might give the greatest contribution, if used for domestic space heating, of possibly up to 4*Q* in the next 100 years.

The prospect of obtaining energy by cultivating photosynthetic organisms for subsequent burning is not bright, since the efficiency of use of sunlight in fixing carbon is less than 0·1%, and pilot plant studies with the most favourable plant materials such as *Chlorella* indicate energy costs about 150 times that of coal.

If we can manage to survive until 1975, the world situation should be very interesting. The U.S.A. will be feeling the cost of high-priced fuel and should be using nuclear power for all central power stations; no doubt we in this country will not be far behind. It will then be possible to see how far high living for a country depends on cheap fuel. Although costs of fuel are a small percentage of total costs, they seem to be tied up to some multiplying factor which causes a drag on the whole economy. If this is so, the American economy will no longer be boosted by unnoticed 'shots in the arm' provided by cheap fuel, and may steady down to levels more comparable to those prevailing in Europe. There will be ample reserves of nuclear energy, 10*Q* a century for several centuries from U.S. uranium deposits alone.

It is hardly any comfort that Russia, China and India face greater difficulties, together with a change in the pattern of living, which must convulse the whole land mass. In India especially the very difficult simple things have to be done first. Some enthusiastic international agency must distribute free solar cooking stoves, or improved ovens which allow dung to be burnt with 20% instead of 8% thermal efficiency, so that the land can receive some fertiliser and produce more food. Some other body has to introduce birth-control methods which are reliable and cheap.

Overcoming fuel difficulties in the industrial countries is going to provide exciting technical work for many of us in our lifetime. In India we may see that combination of excitement and ideals which can provide the basis for a national renaissance.

## THE WRIGHT BROTHERS' LETTERS

The Wright Brothers' aeroplane which made the world's first controlled, powered flight in December 1903 may seem to us, fifty years later, to have been an extraordinarily primitive 'flying machine'.

Perhaps it was, compared with the supersonic jet-propelled fighters, sleek and streamlined, which today can fly from London to Birmingham in ten minutes, or the great airliners which cross the Atlantic overnight. But there was nothing 'hit or miss' about it. Wilbur Wright and his brother Orville put a vast amount of scientific and mathematical study into the designing of their 'Flyer', the aeroplane more commonly known as the 'Kittyhawk', and into the gliders which preceded it in those early flying attempts at Kitty Hawk, North Carolina.

In their workroom behind their bicycle shop at Dayton, Ohio, Wilbur and Orville Wright, who became seriously interested in the study of flight in 1899 by watching birds, built themselves a wind-tunnel. That was in 1901, two years before the first aeroplane flight.

All they did they carefully recorded. Their diaries, notebooks, their letters, particularly the hundreds written to Octave Chanute, the French-born American engineer who began to study aeronautics in the early nineties, are preserved in the Library of Congress.

Now the Wright Brothers' papers have been published.*

Their wind-tunnel was not the first, but it was, as Orville said later, the first which gave results sufficiently accurate to be of use in designing aircraft. The tunnel (they had built a crude one before) was 16 in. square and 6 ft. long. It had a glass window through which they could watch their tests. Driven by a gas-engine, a belt-driven two-bladed fan created a blast of between 25 and 35 m.p.h. The Wrights designed balances on which they could test different wing sections.

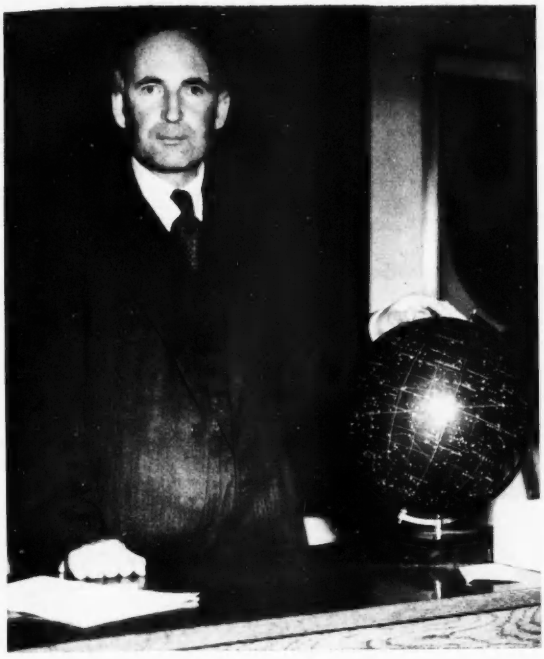
Their records show that in less than a month they tested between 100 and 200 model surfaces, plane and curved, at angles of attack between 0 degrees and 90 degrees. They discovered or deduced hitherto unknown facts about aspect ratio, the shapes of leading edges and trailing edges and many other things which helped them in their design work.

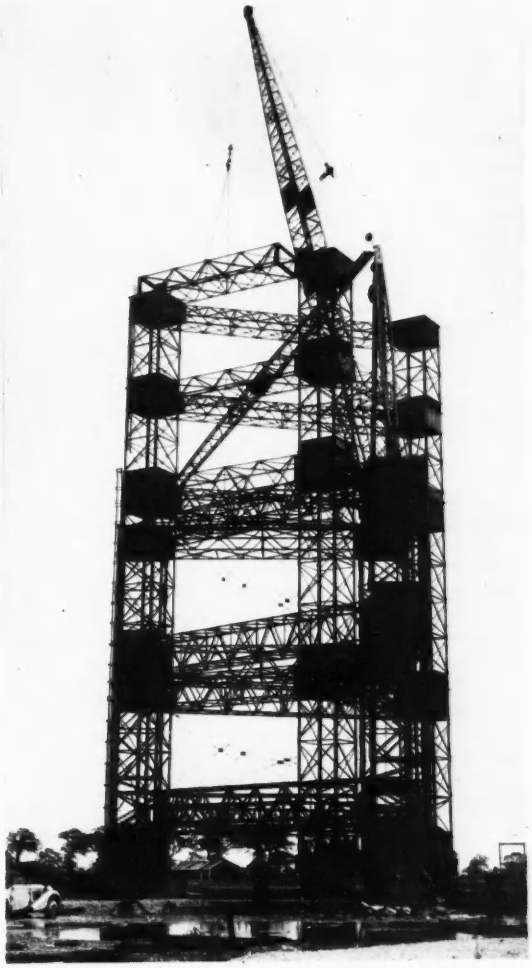
For several months before the first flight, Wilbur and Orville Wright carried out tests with propellers, and their notebooks show in detail how they estimated what those propellers would do. For example, they computed as early as March 1903 that the propellers would give only 66% efficiency owing to the loss from 'slip' and movement of air.

The Wrights had been interested as boys in the early gliding experiments, especially those of Otto Lilienthal. Then in 1899, through reading a book on ornithology, their interest was again aroused. Orville said later, "We could not understand that there was anything about a bird that would enable it to fly that could not be built on a larger scale and used by man."

So, in May 1899, Wilbur Wright wrote to the Smithsonian Institute in Washington asking for all their papers on flying and a list of other works published in English. He said, "I am an enthusiast, but not a crank in the sense that I have some pet theories as to the proper construction of a flying machine. I wish to avail myself of all that is already known and then if possible add my mite to help on

* *The Papers of Wilbur and Orville Wright*. Edited by Marvin W. McFarland, Aeronautics Division of the Library of Congress; two volumes, published by McGraw-Hill; 1953, 1278 pp., £10.





The foundations for the £350,000 steerable radio-telescope, which is being built at Jodrell Bank Experimental Station of Manchester University, are now complete. These two photographs were taken when the Press visited the station on June 10 to see how the project is progressing under the direction of Prof. A. C. B. Lovell (*left*), who described the salient features of the telescope's design in our May 1954 issue. (*Right*) The paraboloidal bowl of the telescope, which will be 250 ft. in diameter and will weigh 500 tons, will be constructed in situ by the steel erectors. The scaffolding which will be necessary for this work and the construction of the two steel towers to support the bowl is here seen in process of erection.

the future worker who will attain final success." From this first move, the Wrights studied the works of Leonardo da Vinci, of Sir George Cayley, Sir Hiram Maxim, Parsons, Alexander Graham Bell, Horatio Phillips, Lilienthal, Edison and Dr. S. P. Langley, the head of the Smithsonian Institute. They started experimenting with kites straight away. When they turned to gliders in 1901, they made careful mathematical calculations of what might be done, and every glide was analysed afterwards.

The brothers were soon torn between their experimental work and the bicycle business in which they were in partnership in Dayton. In October 1901, while they were carrying out their wind-tunnel tests, Wilbur Wright wrote to Octave Chanute:

"We feel very much the generosity and kindly spirit which has prompted your offers of financial assistance in our experiments. For the present we would prefer not to accept it for the reason that if we did not feel that the time spent in this work was a dead loss in a financial sense, we would be unable to resist the temptation to devote more time than our business will stand. . . . Practically all of the expense of our aeronautical experiments lies in the time consumed, and we do not wish to increase the temptation to neglect our regular business for it."

Later that year, Chanute was suggesting that Andrew Carnegie might be approached to give the Wrights ten thousand dollars a year to carry on. (They had shut down experiments for a few weeks owing to the 'busy season' in the cycle business.)

Wilbur Wright's reaction to this suggestion was: "Of course, nothing would give me greater pleasure than to devote my entire time to scientific investigations, and a salary of ten or twenty thousand a year would be no insuperable objection, but I think it is possible that Andrew is too hard-headed a Scotsman to become interested in such a visionary pursuit as flying."

# MICRO-ORGANISMS ON PRODUCTION

A. L. BACHARACH
M.A., F.R.I.C.

The part played by bacteria and moulds and yeasts in controlling and modifying natural processes is today widely appreciated. We recognise as fundamental their task of breaking down dead tissues, both animal and vegetable, so that there remain ultimately only carbon dioxide and nitrogen and water and the mineral residues of plant and beast. When the micro-organisms responsible for organic decay have finished their jobs, everything is either gas or ash. Thus nitrogen becomes available for re-incorporation in the soil, again by virtue of bacterial activity, and thus the carbon dioxide can return to the plants as the result of photosynthesis; similarly the potassium and sodium and calcium and phosphorus and other 'mineral' elements from living matter also go back to the soil for a new passage through plant and animal. None of these processes could take place without the intervention of micro-organisms, animal as well as vegetable; this fundamental, though elementary, fact of biology is—or at any rate should be —taught in every primary school.

Long before the microbiological nature of these changes was appreciated, indeed before even the existence of bacteria, fungi and yeasts was envisaged, man had been engaged in certain productive processes, probably almost as old as himself, that depended entirely on their action. Outstanding among them are the production of alcohol, whether as wine or beer, and the production and maturation of cheese. It is perhaps not so generally appreciated that other foods, as well as some inedible commodities of trade, depend for their qualities on the intervention of bacteria. This is true, for example, of cured bacon, of properly processed tea and cocoa and of tobacco, among other materials. In many of these, the fermentations brought about by the micro-organisms are additional or subsidiary to those depending on the raw material's own natural enzymes. Nevertheless, it is legitimate to include these processes of preparing foods and other consumer goods among those in which micro-organisms play an essential part.

The scientific age of microbiology began with Pasteur and his contemporaries, who were the first to recognise the essentially fermentative nature of bacterial action; yet, despite the immense scientific advances they set in motion, there has been little but superficial change in most of these traditional industries. To some extent the nature of the micro-organisms used has been established and their behaviour standardised by genetic and environmental control. In cheese-making, for example, there has been much talk, and some practice, of using 'pure cultures' of moulds to produce the flavours and textures characteristic of particular cheeses. But many of these processes still depend on the entirely adventitious presence of micro-organisms—in the fermentation of cocoa they are yeasts—deposited on the plant after culling at the place of growth.

The application of scientific knowledge to fermentation processes has been along lines different from any attempt at complete control of our wine, coffee and cigars! Out of several of these traditional industries there have sprung manufacturing processes closely allied to them; outstanding, again, is the production of alcohol, though here for industrial purposes, by the yeast fermentation of molasses and other sources of simple sugars. This process, which has a history as old as the chemical industry itself, has of recent years met a serious rival in the synthesis of alcohol (ethanol) from cracked petroleum products. It seems that the battle between the two is fairly level pegging; this means, in effect, that it depends largely upon the cost of raw materials which of the two processes is dominant at any particular time. It is fair to say that a marked increase in the consumption of rum, with a consequent shortage in supplies and consequent rise in cost of unwanted molasses, may cause an increased use of petroleum for cracking, to give ethylene or other compounds required for synthetic alcohol manufacture.

Analogous with the manufacture of alcohol is the fermentative production of lactic acid, used on a large scale in the pharmaceutical and other industries; it is based on the souring of milk essential to cheese-making. This, although it is also a microbiological process, is due to acid-forming bacteria, and not to yeasts. Then there is the manufacture of acetic acid, which derives from traditional methods of vinegar-brewing, though here again the use of petroleum products has become an important rival. There are other industrial chemicals for whose production microbiological processes continue to hold their own; outstanding among these is the production of citric acid by the mould *Aspergillus*.

Manufacturers of acetone have, on paper at any rate, a choice of methods. In our textbooks of organic chemistry we learnt that it was first made by the destructive distillation of wood, whereas in our 'practical work' we were instructed to heat calcium acetate in the dry state. However, during World War I the work of Weizmann, Israel's president-to-be, clearly established the anaerobic *Clostridium* fermentation of sugar as the best method till then available for making acetone and at least one other important industrial solvent, butanol. It has been said that the fermentation process for manufacturing acetone alone made victory possible for the Allies, so vital is the supply of acetone to the chemical and explosive industries. In point of fact, the *Clostridium* fermentation had been developed for butanol production and at first the acetone was a more or less unwanted by-product. Yet today the fermentation process for making this still highly important solvent has been almost replaced by its manufacture from petroleum 'cracked' products. According to a recent article by Perlman, Tempel and Burn, the 1951 production of acetone in the United States was 96% from petroleum and 4% by fermentation. Butanol, however, is still made in substantial quantities by bacterial action; the amount so produced in 1952 (United States figures only) was about a fifth of the total, though this was rather under 25% of what had been produced by fermentation in 1944. Thus

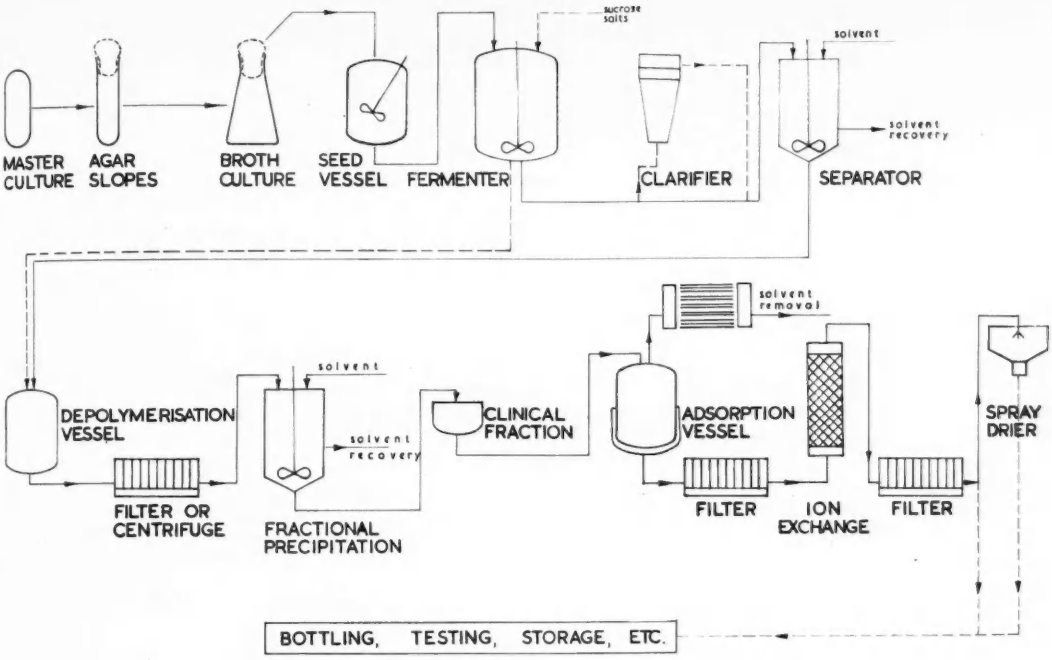



FIG. 1. Stages in the manufacture of dextran by *Leuconostoc* fermentation.

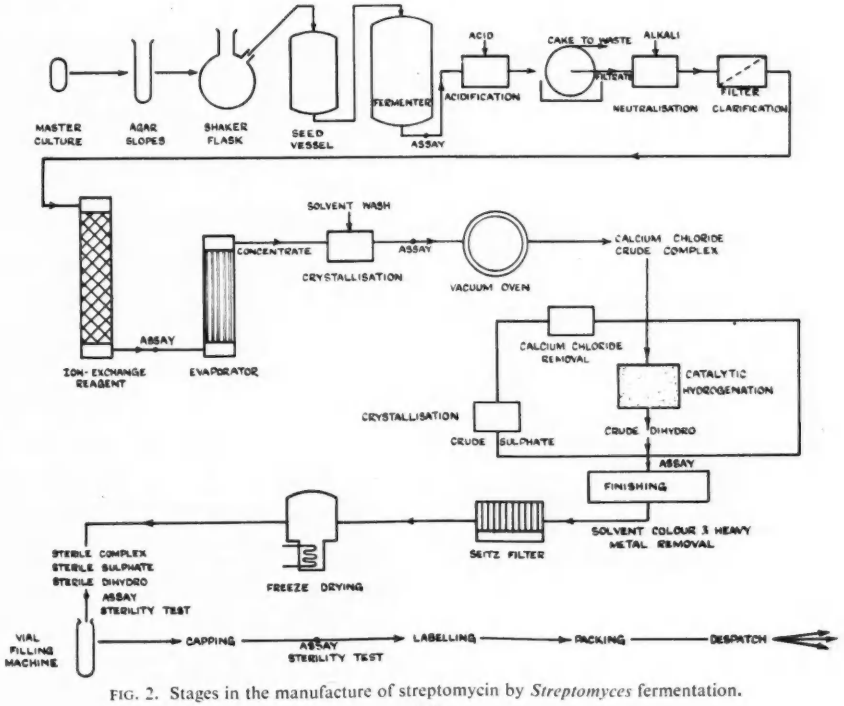



FIG. 2. Stages in the manufacture of streptomycin by *Streptomyces* fermentation.

we appear to be passing through a time when some fermentation processes that have held the ground for a considerable period against defeated chemical or chemurgical procedures are themselves once more in hazard because of the chemist's skill and ingenuity, particularly the skill of the petroleum organic chemist and of the chemical engineer. But to my mind the nature of the ultimate victory in some of these struggles between chemist and microbiologist, between petroleum and bacterium, is less important than the question whether or not micro-organisms may not yet have fresh worlds to conquer for man, their master.

Anyhow, it is not my intention here to list the chemicals at present produced by the action of micro-organisms, whether exclusively or in competition with other processes, for I want to direct particular attention to the latest, and to my mind the most interesting, developments in man's use of micro-organisms to satisfy his industrial requirements. These developments, though in many ways connected with the traditional and the more modern processes already mentioned, have both a different origin and a different aim, and may well require a different approach by research worker and industrial technologist. This, at any rate, appears to have been the view of the president of the Royal Institute of Chemistry, Sir Harry Jephcott, in his address to the Institute's Annual General Meeting at Cambridge in April. He emphasised, though speaking as a chemist, the fundamental part that the biologist has to play in the new fermentation industries and the impossibility of the chemist's getting on with his part of the job until the biologist has laid down the broad lines of procedure to be followed.

The story of the antibiotics has been told so often that there is no need to repeat it here; what is not realised besides their immense importance in medicine is the stimulus their production has already given to those who see in micro-organisms possible 'manufacturers' of chemicals that cannot so far be made by other means or can only be so made less efficiently. It is often forgotten that one of the stages in manufacturing ascorbic acid (vitamin C), developed two decades ago, was found to be so much more efficiently carried on by a bacterium (one of the acetic acid-producing group) as to make it unnecessary to spend any further time on attempts to adapt orthodox chemical methods for doing it. A similar replacement of chemical reagents by moulds, more recent and even more surprising, is their use at a particular stage in cortisone synthesis, where the introduction of an oxygen atom into an awkward place in one of the carbon rings of the steroid skeleton is done with ease by at least two different micro-organisms, both of which have been made the principal agents, not to say reagents, processes patented by United States manufacturers.

Apart from such at present isolated examples of micro-organisms being used to carry out a particular stage in a serial chemical synthesis, there is the production of the antibiotics themselves. Of these, two are manufactured on a large scale in this country, while these two and at least four others are in commercial production in the United States. Of the antibiotics developed industrially, only one is now made synthetically, and most authorities hold the view that these complex and unusual molecules, differing widely among themselves in structure, are among the least likely of all man's chemical requirements to be met by man without the intervention of an appropriate other micro-organism. Of particular interest in the antibiotic field is the active part played by members of the group Actinomycetes, of which the genus *Streptomyces* has so far proved the most important. These are soil organisms, roughly intermediate in biological properties between the moulds and the bacteria, and it seems likely that there is an ecological rather than an accidental basis for their production of powerful antibacterial substances. It may be that the balance of soil microbiological flora and fauna is the result of internecine strife in which the combatants are unicellular plants and animals, the ammunition antibiotics.

In the field of antibiotics there has been an extensive and systematic attempt to find additional organisms capable of large-scale culture for industrial biosynthesis. Many genera, numerous species and very large numbers of strains, particularly among the Actinomycetes, have been put through the hoops—and with some signal successes. For other purposes luck at least as much as cunning has led to useful developments. Of unusual interest has been the exploitation of a bacterium—*Leuconostoc mesenteroides*—for the commercial production of dextran, a high molecular weight polymer of glucose, in increasing use as a plasma 'expander' or substitute and for some other more specialised therapeutic purposes.

Again, it was as a result of luck, always associated with a watchful and scientifically controlled look-out for unusual happenings, that the elaboration of vitamin $B_{12}$ by Actinomycetes was discovered and exploited. This now famous substance, officially called cyanocobalamin, is used for maintaining sufferers from pernicious anaemia in normal health; it is to them what insulin is to the diabetic. When first prepared it was thought to occur nowhere except in the livers of mammals and other higher animals.

Vitamin $B_{12}$ is not the only vitamin today manufactured microbiologically, leaving out of account the bacterial stage in making vitamin C. The important substance riboflavine, which is in general demand for addition to poultry feeding-stuffs, especially in the United States, is today made almost exclusively by the action of a bacterium belonging to the *Clostridium* group, although other bacteria and yeasts have also been used for the purpose. An essential for normal growth, and a preventer of a serious deficiency condition in chicks, riboflavine is increasingly being accepted as capable of raising the grade of poultry feeding-stuffs.

Perhaps the strangest by-product of microbiological work in an unusual field has been the discovery of bacterial means for making elementary sulphur, which is always a potential source of much needed sulphuric acid, considered by many to be the key substance of the chemical industry, and hence of several others. The discovery arose from investigations into the corrosion of buried iron pipes and the finding that this is at any rate in part due to the action of bacteria that can reduce sulphates in the soil to sulphides. The matter has been the subject of intense study by Dr. Butlin and his colleagues at the DSIR's Chemical Research Laboratory, Teddington. Although their work

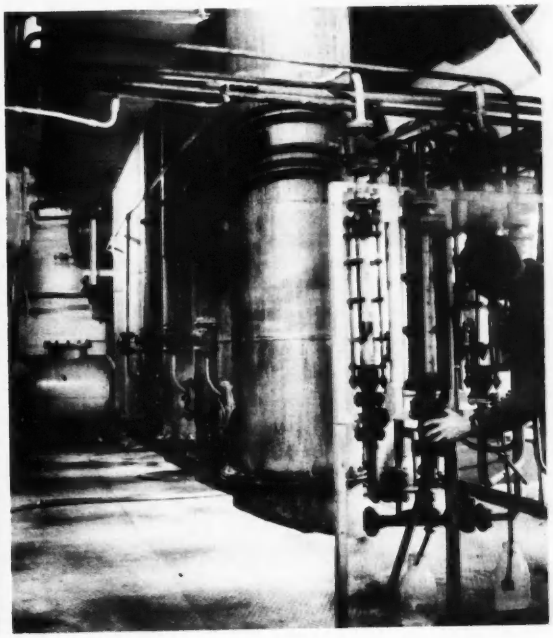
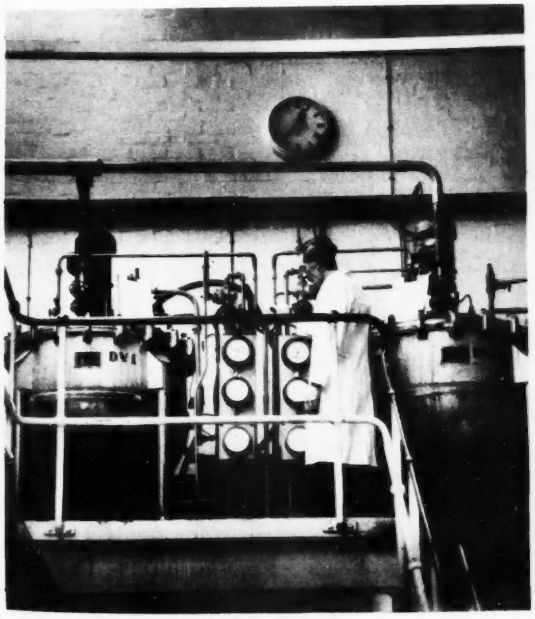


FIG. 3. Lower third of tanks used in manufacture of vitamin $B_{12}$ (cyanocobalamin) by fermentation. FIG. 4. Part of adsoption towers used for concentration of vitamin $B_{12}$ from fermentation liquors



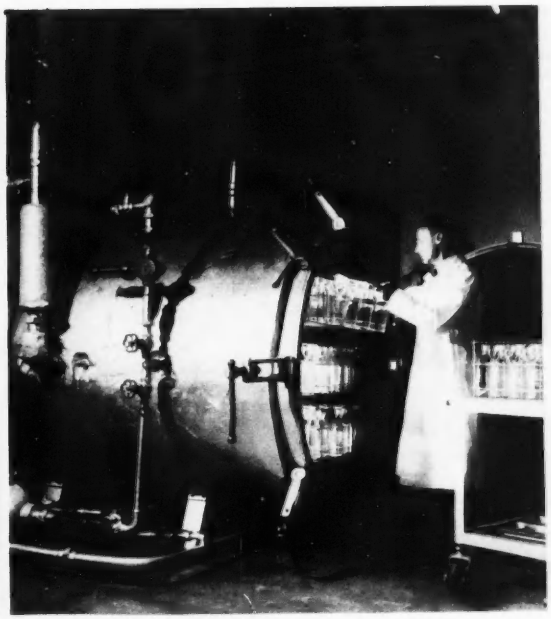


FIG. 5. Evaporators for removing acetone after precipitation of dextran from fermentation liquors made by *Leuconostoc* fermentation. FIG. 6. Autoclave for controlled sterilisation of packed dextran solution, ready for clinical use, made by *Leuconostoc* fermentation. (*Glaxo Laboratories pictures*)

was first mentioned in the DSIR's Annual Report as recently as in the one for 1948–9, substantial progress has already been made. The most promising source of bacterially produced sulphide—and hence of sulphur dioxide, hydrogen sulphide and elementary sulphur—now appears to be unsterilised sewage sludge; the 1953 report of the Chemical Research Laboratory records experiments on the simultaneous production from sludge of both sulphide and methane, a 'combined operation' that, in the opinion of the investigators, might make the process a 'business proposition'. At present, however, chemical methods of using the sulphur of anhydrite for making sulphuric acid hold the field on economic grounds. All the same, these wholly British researches in applied microbiology might at any time provide a second line of defence against another threat of a world sulphuric acid shortage.

So far the selection of substances to be made by bacterial action rather than by conventional chemical synthesis seems to have been not merely arbitrary, but just due to chance. It is known, for example, that bacteria of the alimentary tract have remarkable powers of synthesising many of the vitamins, both water-soluble and fat-soluble, yet there appears to have been little practical exploitation of this property as an alternative to elaborate, and consequently expensive, methods of total or partial synthesis, which are at present used as the only economic alternatives to extracting these substances from natural sources. One reason for this apparent lack of enterprise is, no doubt, the small medical demand for some of these vitamins; they appear to be inadequately present only in the diets of those that cannot afford to buy them as food supplements!

Nevertheless, there is at present a climate of opinion, spreading perhaps more rapidly than some imagine, that a much more systematic study, jointly by industrial biologists and chemists, might reveal many possibilities of replacing inefficient or otherwise expensive chemical stages in manufacture by large-scale 'fermentations', particularly today when the technique of these processes has been so thoroughly developed by the antibiotic manufacturers. There seem to be two main directions in which the chemist may seek aid from micro-organisms, and they are, paradoxically, at almost opposite ends of the scale of complexity.

First we have the use of moulds and bacteria, and particularly of Actinomycetes, to produce highly elaborate molecules, whose chemical synthesis has either not been worked out at all or offers little hope of large-scale practical application. Anyhow, the question of chemical synthesis here does not generally arise at all: these particular substances have been discovered as products of microbiological action after investigations involving the testing of large numbers of strains; the controlled culture of the right one for use in biological synthesis has naturally become the only known process of production and there seems little advantage to be gained from search for an alternative. The other types of reaction to which bacteria seem specially suited are among the simplest of all, such as the reduction of sorbitol to sorbose by just adding hydrogen and the insertion of the 11-oxygen atom in the sterol nucleus for cortisone 'synthesis'. Might it not be worth while to survey the synthetic chemical industry, even such branches as the manufacture of dyestuffs, with the object of discovering whether there are other apparently simple stages that have been found difficult to carry out with reasonable efficiency by chemical means and could be done microbiologically?

One of the biggest obstacles to overcome in pursuing this development lies in the gap that is only slowly closing between the biologist, particularly the microbiologist, and the chemist. Whereas the latter has for decades become accustomed to regarding a career in industry as at least normal, and in no way inferior in status to that of his academic colleagues, microbiologists, except for the few who are lucky enough to obtain posts in breweries, have only to a limited extent had any industrial orientation at all. In part this is no doubt due to the intense medical hegemony that has existed for a century in the field of bacteriology and is only now beginning to be challenged by the growing number of applied biologists of all kinds. If these include sufficient applied microbiologists and if they are convinced that they have a useful and recognised part to play in the world of industrial chemistry, it is possible that some of the tougher problems of chemical synthesis might be solved by methods of which no one at the beginning of the century could possibly have dreamed.

Such microbiologists, with a sound basic knowledge as well as an interest in its creative practical application, are at any rate in theory the possible colleagues of the synthetic chemists, who are themselves now aware that micro-organisms may be available—or discoverable and even creatable—to help them over some of their hurdles. Organisms that can reliably produce such large and unusual molecules as that of vitamin $B_{12}$ (molecular weight about 1500) or placidly insert an oxygen atom in a steroid ring to which chemists cannot get access are versatile allies not to be despised.

Let there be, however, no mistake about the amount of preliminary work to be done before any far-reaching alliance can be established. Much more knowledge will be needed of techniques for producing and studying new strains of bacteria, moulds and yeasts. Some of the many possible ways of attacking the problem are shown in the 1953 issue of *Chemical Research*, to which I have already referred. Various methods used by the geneticist to produced, isolate and stabilise mutations, and others used by the biochemist to discover exactly what chemical reactions can, so to speak, be got to 'interest' a micro-organism, will need to be applied to hundreds or thousands—even to hundreds of thousands—of specimens. The workers at Teddington have indeed been applying them to certain soil-organisms, but only to a handful of strains, in a study of the way micro-organisms break down the aromatic (benzene) ring under natural conditions. Their researches are undoubtedly being handicapped by inadequate staff (inadequate in quantity, though most certainly not in quality) and accommodation, for the group at Teddington might well have petri dishes made in the shape of glass slippers. Will industrial chemistry be prepared to act the Prince to this scientific Cinderella?

READING LIST

Three articles on this subject by G. Colman Green were published in DISCOVERY (Vol. V, 1944, pp. 334–9, 370–4: Vol. VI, pp. 20–7). Two books on this subject are: George Smith's *An Introduction to Industrial Mycology* (Arnold) and Prescott & Dunn's *Industrial Microbiology* (McGraw-Hill).

# KNOW-HOW v. PATENTS: NEW TRENDS IN THE SOCIOLOGY OF INVENTION

JACQUES BERGIER

*Many inventions are fully described in patents (of which over 675,000 have now been granted in Britain since the year 1449 when the first patent—for the making of coloured glass for the windows of Eton College—was awarded to John of Utynam in the reign of Henry VI), but there is growing tendency nowadays for new technological developments to remain unpatented and remain instead as a matter of know-how—which is the expressive American term applied to technical 'tricks of the trade' that for a variety of different reasons remain unwritten, though this is not the same thing as saying that all items of know-how are 'trade secrets', because some matters of know-how simply defy written description. The essence of know-how is to be able to bring to bear all the relevant factors which enter into a specific complex industrial process so that successful operation of that particular process can be guaranteed, whereas one slip could bring virtual failure and might take months to track down and correct. The advance of scientific explanation of industrial processes can make know-how of less value, but it must be realised that know-how does not remain stationary: as scientific understanding of a particular industrial process increases so new know-how accumulates. This article originally appeared in the Unesco journal,* Impact, *and we reprint it here because the somewhat unorthodox opinions which it expresses are of such great general importance; these opinions, we would add, are purely personal opinions of the author's, but even though we disagree to some extent with his remarks about British patents we think that his general line of argument is thoroughly sound and will be of interest to our wide readership.*

From time immemorial inventions have been a great social force. The horse-collar, gunpowder, the compass, movable printing type, etc., have resulted in far-reaching changes in the pattern of civilisation. Up to the 19th century, however, inventions were few and far between, and the social changes they produced were a slow process, generally extending over a long period of time. Gunpowder, for instance, made its appearance in Europe early in the 14th century; but artillery was not used as the dominant weapon until the siege of Constantinople, some 150 years later, and firearms continued to undergo adaptation for another two centuries, until the end of the Thirty Years War. Similarly, the compass was known in Europe, in a rather primitive form, at least two or three hundred years before it became one of the main instruments of the great geographical revolution towards the end of the 15th century.

It was not until the 19th century that inventions really began to revolutionise, at an ever-increasing pace, the whole political, economic and social structure. The obvious reason was the emergence of technology. Technology was what made the 19th century so entirely novel and unique, so unlike all the centuries that had gone before. As Whitehead remarks, "the greatest invention of the nineteenth century was the invention of the method of invention . . . that is the real novelty, which has broken up the foundations of the old civilisation".* This statement is not entirely accurate, as we are still far from having probed the psychological and social mechanism of invention; but it is true in that we have, undoubtedly, brought about conditions conducive to an enormous increase of inventions.

One of the most important of these conditions relates to the legal provisions governing the ownership and use of inventions. Such provisions came into existence in the early 17th century, but only with the birth of technology in the 19th century did they attain their real social significance. Indeed, the Industrial Revolution with all its political, economic and social consequences is hardly conceivable without this legal device that goes by the name of 'patent'. But though, for a century and a half, the patent was essential to technical and industrial progress, its heyday now seems to be past. Its place is gradually being taken by something more in line with the technical requirements and social trends of our age—the know-how.

* A. N. Whitehead, *Science and the Modern World*, Cambridge University Press, London, 1926, Chapter VI.

## THE CONCEPT OF PATENTS

The concept of patents goes back to the early 17th century—to the Statute of Monopolies of James I of England. This statute, promulgated in 1623, was designed to abolish the privileges and monopolies which were current at that time and were regarded as a veritable social scourge. It declared all monopolies null and void, with the exception of letters patent and privileges granted to the inventors of new products or manufactures, but "so as also they be not contrary to the law nor mischievous to the State by raising of the prices of commodities at home or hurt of trade or generally inconvenient". This definition is still, to a large extent, the guiding principle of all patent legislation.

It is interesting to note that the concept of a patent was not entirely divorced from theological considerations. The idea of patents arose in England at a time when the law was particularly strictly directed against witchcraft; and it also reflected a reaction against alchemy. Any inventor publicly revealing his secret thereby showed that he had not concluded a pact with the powers of darkness. Thus Neper, the inventor of the logarithms that bear his name, wrote on the first page of his book (published in Latin in 1614): "This miraculous means of making calculations, was worked out with the authorisation of our Holy Mother the Church."

Outside England, however, it was not until towards the end of the 18th century that patent legislation made its appearance in the leading countries. In the United States of America, it was a direct outcome of the 1787 Constitution, Article I, Section 8, Clause 8 of which made formal provision for patents. A Bill on this subject, very

largely modelled on the English system, was enacted in 1790. In France, patent legislation was instituted with the law of 1791. Under the old régime, the king, at his pleasure, granted letters patent to inventors. In Germany, the first patent laws appeared in certain States as early as 1815, but it was not until the Zollverein Convention of 1842 that the principles of an overall German law were laid down. The other countries adopted similar laws, based on the three main systems in force: Anglo-Saxon law is applied, with certain modifications, by all countries of the British Commonwealth; the German system influences the Scandinavian countries, the Netherlands, Austria and Hungary; while French law guides all countries that have adopted the Civil Code.

Generally speaking, the patent was at the outset, and still is, a kind of contract between the inventor and society. The inventor discloses to society the secret of how to work his invention, and society, in exchange, undertakes to reserve for the inventor or his beneficiaries a monopoly in the working of his invention for a period varying, according to the country, from fifteen to twenty years. Even today this period is an appreciable fraction of human life; it represented a much larger fraction at the time when patent legislation was beginning to evolve. In brief, the law is based on the principle that society grants the inventor an exclusive or monopoly solely because of the value, to society, of his invention. The obvious corollary is that, if that value to society is for any reason impaired, the monopoly granted to the inventor ceases to be justified. As we shall see later, it is the interpretation, in a particular way, of this principle which is basically responsible for the present depreciation in the value of patents.

In fact, the present-day concept of the social utility of patents is somewhat akin to that which inspired the drafting of Anglo-Saxon legislation, namely that the patent was a monopoly and, as such, was to be regarded with disfavour by the law. But in the 19th century this concept had made way for the French thesis that the inventor's right was a natural right, and for the German idea that the patent was in some sort a bargain concluded between the inventor and society.

It should also be noted that the conditions governing the issue of patents vary considerably from one country to another. In France, and in countries which have adopted the French system, the patent is issued without any previous examination of the scientific value or novelty of the invention, and hence without any guarantee from the government (S.G.D.G.).* Great Britain and many of the Commonwealth countries make a point of carrying out some limited investigation into the novelty of the invention and of ensuring that the text describing it is clear. But it was to German patents, and quite rightly, that the greatest prestige attached. Apart from the question of novelty, the German Patentamt introduced the concept of the scientific value of the invention, implying a preliminary investigation of its practicability. Admittedly, the examiners in the Patentamt were not infallible; Bessemer's application for a patent for his converter was rejected on the grounds that his invention was impracticable, Giffard's for the steering of balloons was refused on the grounds that the invention was not serious, and Oberth's for the space ship for interplanetary travel met a similar fate on the grounds that the invention lacked novelty. But apart from these very few human errors, the German examiners, thanks to their admirable analyses and their full bibliographies, have rendered invaluable service to thousands of inventors and industrialists and to the cause of science and technology in general. To obtain a full bibliography on any given subject, it became customary to apply for a German patent on that subject.

The American patent enjoys the same sort of prestige as the German patent. It is not granted until the novelty of the invention has been investigated; and the extensiveness of the research carried out in this connexion is well known —as is also its slowness, which is deplored by inventors throughout the world. The vast library of the Patent Office comprises, among other things, all the scientific fiction magazines that might possibly be taken into account in connexion with the issue of patents. Thus the periscope was regarded as a non-patentable invention because Jules Verne had described it in *Twenty Thousand Leagues under the Sea*; and it is not impossible that science fiction articles may one day be used as grounds upon which to reject applications for patents on interplanetary navigation, for instance. But the American patent also involves a very extensive legal analysis; its claims define with the utmost precision the nature of the invention and the particular rights granted to the inventor; they are a remarkable blend of abstract and concrete, of ideas and facts. American legislation is also more favourable than most other systems to the individual inventor, who often lacks financial resources. In particular, it is the only system under which a single fee is charged, whereas in most other countries the inventor has to pay annual instalments, generally at an increasing rate. This latter procedure is extremely unfair to the inventor, who often needs several years in which to make his invention a paying proposition. Very frequently a French or English inventor loses his patent at the very moment when he reaches his goal, through inability to pay the annual instalments. Another special feature of the American patent is the fact that it is issued only to the inventor himself, who often makes a statement before witnesses as soon as he has thought out the invention and well before the application for the patent is filed.*

Of the other examining offices, special mention should be made of the Swiss office (where Albert Einstein was once an examiner) and of the Swedish and Netherlands offices. At the international level, co-operation between the leading countries was established by the International Convention for the Protection of Industrial Property, signed in 1883 and in force since 1884. This convention safeguards, through the first patent taken out in one of the member countries, the inventor's right of priority in all other signatory states for a period of one year. This obviously does not relieve the inventor of the need to take out a patent in each country where he wishes to safeguard his rights; and this requirement, which involves heavy

* Cf. Jean Pouillet, *Traité des Brevets d'Invention*, Billard, Paris, 1879. (S.G.D.G., sans garantie du gouvernement.)

* On the subject of American patents, see Karl Michaelis, *Praktisches Handbuch des Amerikanischen Patentrechts*, Carl Heymans Verlag, Berlin, 1932.

expenditure, has led to the idea of an international patent. An instrument for carrying this idea into practice already exists in the shape of the International Bureau of the International Union for the Protection of Industrial Property, set up in Berne under the 1883 convention, which now has a membership of some forty countries, including all industrial countries except the U.S.S.R. However, the international patent seems unlikely to be instituted in the near future.

## THE HEYDAY OF THE PATENT

With the progress of legislation during the 19th century, patents, especially those delivered after examination, acquired considerable importance in the business and industrial world. With the help of key patents, many industrial groups were able to acquire a world monopoly in the manufacture of certain equipment or products. The electric filament invented by Edison, De Forest's three-electrode lamp, Bessemer and open-hearth steels, Whitney's loom and McCormick's harvester are instances in point. The patent gradually became one of the classic means of acquiring a monopoly, especially in the Anglo-Saxon countries, where common law was particularly severe upon purely economic monopolies. Private inventors occasionally managed to cover an immense field with their patents. The American Carleton Ellis, for instance, took out 810 patents, none of them without value. To him we owe such inventions as quick-drying paints and varnishes, which play so great a part in the automobile industry; nine-tenths of the plastics now in use; methods of improving edible oils; methods of cracking petroleum, and so on. His first patent was taken out in 1900; his last in 1940, at which time he, as an individual, held the record for the number of patents in industrial use. Since the defeat of Germany, the world has learned that over 1000 patents filed in the name of I.G. Farbenindustrie and used throughout the world were the work of a single man, Dr. Walther Reppe.

The prestige and dignity attaching to patents in the second half of the 19th century and the first quarter of the 20th can hardly be imagined today. The establishment of the Patentamt in 1877 was regarded as a landmark in German history; and Dr. Carl Duisberg, who founded the I.G. Farbenindustrie in 1925, looked upon German patent legislation as one of the country's main sources of wealth. The patent was a title whose value and validity few people dreamt of disputing. Inventors refusing to take out a patent for the better guarding of their secret belonged to the world of popular novels rather than to the world of reality. Few actions were brought for infringement or invalidity. The best illustration of this state of mind is perhaps the attitude of the belligerent countries towards patents in the 1914–18 War; patent offices continued to examine, with great impartiality, applications filed by enemy nationals, and special measures were taken, in co-operation with neutral countries, to prevent any interruption in the payment of annual instalments.

In various countries, the agencies responsible for the administration of enemy property had to undertake the working of enemy patents. In particular, the United States of America, with its (at that time) relatively small chemical industry and almost total lack of large organic-chemical industries, had, during the war, to take over 12,000 American patents (5000 of them in the realm of chemistry) belonging to German nationals. A special company, the Chemical Foundation, was established to buy back the patents seized by the Alien Property Custodian, and to work them. This is the origin of the leading organic-chemical industries, such as the dyestuffs industry, in the United States of America, and it is from this period that the country's large-scale chemical industrial expansion dates.

All these factors still further increased the importance attached to patents. It was generally thought, at the time, that even discoveries concerning aviation or atomic energy would be patented. It should be borne in mind that in 1919 atomic energy was already entering into the realm of possibility: Aston, Soddy and other contemporary scientists were publicly stating their belief that the energy stored within the atom would soon be released, and H. G. Wells, in his book *The World Set Free*, described a suit for infringement involving a public discussion of atomic energy problems. It is significant that in 1919 Professor Robert H. Goddard took out the essential patents for jet propulsion, covering, among other things, the jet rocket from which the German V.2 bomb was derived. Such an attitude would appear inconceivable today, so accustomed have we grown to the idea of inventions as a secret, and of inventions as the property of the State, whereas a patent was by definition a contract between the State and the inventor.

In 1920, however, it is our present ideas that would have seemed inconceivable. The patent was then surrounded by an aura of romance that was frequently conjured up in books and films of the day. In short, it appeared to be one of the firmest bases of technical and industrial civilisation. Yet the first signs of the patent's eclipse could already be discerned.

## THE DEPRECIATION IN THE VALUE OF THE PATENT

The depreciation in the value of the patent is mainly due to two groups of factors—scientific and technical on the one hand, and social on the other.

The origin of this development must first be sought in scientific and technical progress. The growth of parallel techniques for achieving the same result means that the same ends can be attained by several different means. Thus, to examine an object without destroying it, use can be made of magnetism, the electro-magnetic field, X-rays, gamma rays, neutrons, and so on. In other words, modern technology usually provides a way of circumventing a patent, or 'slipping through' a series of patents designed to cover a whole field so as to discourage other inventors. For instance, when the property of copper oxide of converting alternating into direct current was discovered, a leading American company patented the utilisation of all oxides and halogenides of all metals—which meant an enormous number of patents. However, an inventor sidestepped this obstruction by using silicon, which is not strictly speaking a metal. Similarly, any patents on amplifiers using complex assemblies of electronic valves were completely by-passed

by the invention of electron multipliers. In short, with the progress of technology, it has now become far easier to circumvent a patent—and this, obviously, is not calculated to raise the prestige of the patent system.

Another important result of technological progress, so far as patents are concerned, is the increasing complexity of the techniques themselves. Some modern processes are so complicated that it is virtually impossible to describe in the form of a patent or written specifications the exact method of carrying them out. It often happens that a company selling or transferring a patent or process to another firm dispatches, at the same time, a team of technicians who are responsible not only for the starting of the operations but for the actual manufacture of the product in question, sometimes for a period of several years, until the technicians of the firm purchasing the process have gained sufficient experience in its application. In other words, the actual acquisition of a patent does not give the purchaser any guarantee of being able to work the invention. This is a relatively new factor, which is the direct outcome of the growing complexity of modern technology and was not, or was barely, operative thirty or forty years ago.

Lastly, technical progress has had another somewhat paradoxical effect on patents, in the form of the increasing number of applications for patents which are not followed up and thus fall into the public domain. It has, in fact, become progressively more difficult to defend patents before the law courts from the strictly scientific and technical standpoint, quite apart from the social and legal aspects involved, which will be dealt with later. The reason is that such defence necessitates a thorough study of antecedents in the form of previous patents, scientific and technical publications, and sometimes even advertisements. But the vast growth of scientific and technical literature and of the number of patents filed during the first half of the 20th century has made such a study extremely costly. Accordingly, an increasing number of applications for patents are not followed up, and the relevant inventions fall into the public domain. It is estimated that in England and the United States of America, as well as in pre-war Germany, three out of four applications for patents were allowed to lapse. Some companies have a research service specialising in this 'anti-patent' work; thus, ballpoint pens were not placed on sale until the patents for them had fallen into the public domain.

However, difficult as it now is to defend the patent at law from the purely scientific and technical standpoint, it has recently become yet more difficult to defend it on legal grounds. This is where social factors enter into the case.

It should first be stated that an action for invalidity may be brought against any patent, whether issued without examination, as in France, or after examination as in the case of English, American or German patents. In such cases, jurisprudence is often of more account than the letter of the law. But even the law is often vague and disconcerting; it hardly ever defines what *is* patentable, but is generally content to define negatively what *is not*.* As for jurisprudence, it is often so contradictory as to undermine the very notion of patent.* For instance, pure acetylsalicylic acid (aspirin) is declared patentable in the United States of America, whereas a pure metal such as tungsten or molybdenum is not. In *Mineral Separation* v. *Hyde*, the United States Supreme Court ruled that the reduction of the quantity of oil used for the floating of slimes (ore), from a few kilograms per ton to a few grammes, was patentable, because there was a difference in quality; but in *Metal Hydrides* v. *Patent Office*, the same court declared that the reduction of impurities in tungsten, uranium, vanadium and thorium from a few per cent to less than a thousandth was not patentable. Furthermore, American judges are showing an increasing tendency to rule that an invention which has required many years' study and the collaboration of many scientists is non-patentable, on the grounds that there has not been 'a flash of genius' and that another team of scientists would necessarily have arrived at the same result (*Cuno Engineering* v. *Patent Office*, before the United States Supreme Court). But inventions which result from a flash of genius are increasingly rare. Modern invention is essentially the result of teamwork and long years of research, and firms that devote large sums of money to such research obviously do not like to be deprived of the fruit of their labours by the patent falling into the public domain.

It should further be mentioned that the courts often come up against extremely subtle technical problems. In France, for instance, there have been lawsuits where it was necessary to decide whether the use of a stereoisomer of a substance instead of the substance itself constituted an infringement, or whether the use of a magnetic field created by an electro-magnet instead of a permanent magnet constituted a novelty (electrodynamic loudspeaker).

It should be emphasised that the change over the past twenty or thirty years has been not so much in patent legislation as in the interpretation of that legislation. Jurisprudence has always been largely dependent on social trends, and judges more often than not reflect the views of the society to which they belong. Social concepts of ownership have evolved considerably over the past fifty years. The progress of socialist ideas and the growth of State intervention in the economic field, even in countries whose ideas are not socialist, have well-nigh swept away the concept of the inviolability of private ownership so characteristic of the 19th century and still so deeply rooted in most countries before the Second World War. In the field of invention, this trend is reflected in the growing and sometimes excessive subordination of the interests of the inventor—whether the latter be an individual or a firm—to those of society. This trend is accentuated by the general public's growing hostility towards monopolies—an understandable and almost natural reaction against the development of trusts and the abuses of monopolies between 1870 and 1930.

This tendency to break down monopolies, so characteristic of our time, is probably the most important factor in the present-day depreciation of the patent system. Public

* See Armand Picard, *Précis de Brevetabilité*, Dunod, Paris, 1928.

* Cf. Robert Moureaux and Charles Weismann, *Les Brevets d'Invention*, Dalloz, Paris, 1926; M. Massius, *Traité des Brevets d'Invention*, Billard, Paris, 1931.

opinion demands the abolition of monopolies, and jurisprudence is obliged to follow. In England, the examination of patents is becoming more and more a matter of form rather than of substance. In Germany, perfectly valid patents have occasionally been invalidated for fear of displeasing public opinion. In the United States of America, the Supreme Court quite frequently invalidates patents submitted to it, for reasons often so contradictory as to have given rise to the saying that "invention, like the Constitution, is what the judges say it is".* Such an attitude has naturally resulted in a considerable lowering of the prestige and value of patents. Accordingly, the concept of patents has gradually given way to the concept of know-how.

## THE CONCEPT OF KNOW-HOW

Know-how may be defined as the body of knowledge necessary for the effective application of a new process. In this respect the concept of know-how is in line with the original concept of patents, which, at the outset, contained all the know-how necessary for their application. But, unlike the patent, know-how brings with it no legal protection. As we shall see later, it may be kept secret or sold or transferred or disseminated free of charge, but in no case has it the legal character of the patent.

As know-how is essentially an art of reproducing, it involves an exact definition of the conditions required for working a process or obtaining a product. This definition in turn calls for precise measurements of certain properties and characteristics, and it is worth noting that the concept of know-how had necessitated the creation of new measurable properties, such as fluidity, plasticity, the rate of modulation, the purity of a signal, etc. It has also been necessary to devise new measuring instruments, such as the photocolorimeter, or to adopt new concepts (e.g. photoelasticity), on which new methods of measurement are based. It is essential to realise that know-how is something more than sleight-of-hand or a manufacturing secret; it is a scientific and extremely precise description of a usually highly complex technique, so complex that, with the best will in the world, it is generally difficult to communicate and calls for considerable scientific competence on the part of all concerned. As in the case mentioned in connexion with patents, it frequently involves dispatching a team of technicians for an extended period, to familiarise the licensee with the details of the process.

Moreover, it often happens that the know-how is not accurately enough known to be communicable. In many cases, we cannot say what distinguishes a good from a bad product. A good instance is provided by battery carbons. The most delicate methods—electronic microscopes, X-ray diffraction, the diffraction of neutrons—have proved inadequate to distinguish a good carbon, which will make the battery last for years under difficult operating conditions (railway signals, automatic rural telephones), from a poor carbon which will lead to a drop in voltage after a few months. The same seems to apply to the aluminium covering of uranium bars used in atomic piles (canning). It has never proved possible to transfer the manufacture of harmonicas from Germany to France, or the manufacture of glass balls used for 'cat's eyes' from Czechoslovakia to Germany. In each case there is lacking one or more of the new measurable properties capable of defining the state of the product and the know-how of its manufacture. Generally speaking, when it is said that the manufacture of a particular product is an art rather than a science, this means that it has been impossible to systematise the know-how in this field. It remains true that, when it is worth while, some means of systematising the know-how is invariably found, as in the case of the manufacture of radar magnetrons (transfer of know-how from England to the United States of America) or of penicillin (transfer from the United States of America to the rest of the world). Most of the atomic 'secrets' are extremely complex techniques which are, in fact, know-how.

## KNOW-HOW—INDUSTRIAL PROPERTY

Although the know-how affords no legal protection, it is none the less a form of industrial property which, like a patent, can be negotiated. Quite often it is the complement of a patent or of a series of patents. But whereas the acquisition of a patent gives the patentee no *technical* guarantee of being able to work the process or manufacture the product in question, such a guarantee is, by definition, conferred by the know-how, as the latter is essentially an art of reproducing.

Unlike the patent, however, the know-how gives no *legal* guarantee against the working of the process by others who have managed, independently, to discover the technique. Yet the know-how, when sold, costs far more than the corresponding patent. When the patent alone is sold, it is customary to pay a royalty of approximately 2% of the turnover; but with the sale of the patent plus the know-how, or of the know-how alone, the royalty is in the vicinity of 8%. The know-how may also be sold for a lump sum; recently an American group transferred to a Turkish group, for a sum of $17,000,000, the know-how for the manufacture of fertilisers. In other cases, the know-how may be transferred in exchange for a share in the purchaser's business; this was what happened when I.G. Farbenindustrie and the Japanese Government concluded a transaction concerning the synthetic petrol plant in Manchukuo.

Know-how alone, without the corresponding patent, is sold mainly in the following cases:

1. When the patent has fallen into the public domain (as recently happened when Twentieth Century-Fox bought the French 'Cinemascope' or 'Hypergonar' process for three-dimensional films).
2. When the patent has not been filed in the country of the licensee (a frequent case in under-developed countries, such as India, Pakistan, Egypt, certain Latin American states, etc.).
3. In the case of techniques which are not patentable because of their complexity or owing to legal considerations (fluorescence, manufacture of filaments for incandescent lamps, of cathodes for electronic tubes, etc.).

* John C. Steadman, "Invention and Public Policy", *Law and Contemporary Problems*, XII (1947), p. 664.

There is perhaps no better illustration of the present-day importance of know-how than the efforts made by the Allies, towards the end of the last war, to acquire the secrets of German and Japanese techniques. Three teams of scientists and technicians—known by their code-names Bios, Cios and Fiat—went through the Axis factories and plants and assembled all information on German and Japanese industry and technique. What was sought here was simply the know-how, as the corresponding patents were already well known. This vast body of technical information was eventually made available to the public free of charge. One only needs to order a microfilm in Paris, London or Washington to acquire, against payment of the costs of reproduction, a know-how which, before the war, would have been worth millions of dollars.

This is not the only instance in which the know-how has been handed over free of charge. Certain official bodies, like the United States Bureau of Standards or the National Research Development Corporation in Great Britain, are constantly conducting research and developing techniques whose results are made available cost-free to interested parties. But even industrial firms occasionally find it advantageous to place the know-how of certain processes at the disposal of their competitors free of charge. As a matter of fact, in the case of a widely used product, mass manufacture by several firms creates new needs which fully warrant the free disclosure of know-how and the loss of the monopoly. In the long run, the product becomes so widely used that the firm which gave the secret away sells far more than it could have done if it had kept the monopoly. Furthermore, the disclosure of a process arouses the interest of scientists and engineers throughout the world, and encourages them to perfect the process and sell their improvements to the firm which developed the process in its original form. Thus the divulging of the secret is usually a spur to technical progress. For instance, Dupont de Nemours found it worth while to reveal the know-how of their process of manufacturing cellophane. But this has not always been the case. Until quite recently, a large European firm manufacturing pneumatic tyres used, in its workshops, thermometers graduated in $x$ degrees and viscosimeters graduated in $x$ units so as to prevent any leakage of know-how.

Such an attitude is becoming increasingly rare today, especially in the United States of America. The American, Frederick Lewis Allen, recently wrote in this connexion: "A prominent characteristic of modern industrial trade associations is the amount of information they collect and make available to everyone in industry. . . . One thing that almost every foreign businessman exclaims at in America is how few secrets there are."*

To a certain extent this new attitude is due to the motives of personal interest we have mentioned. Enlightened industrialists and businessmen find that it is often more profitable, from the purely material standpoint, to reveal their secret of manufacture than to keep it. But it is also largely due to the change in social outlook brought about by the two world wars. The action of governments against cartels, especially in the United States of America, is one of the most striking symptoms, and no month goes by without some new decision on the subject being announced. Quite recently, the United States Federal Court ordered the United Shoe Company, one of the largest firms in the world, to grant a licence of its patents to all its competitors. This decision, taken after examination of a file running to 14,194 pages and of 5512 exhibits produced in evidence, deals the death-blow to one of the world's last monopolies based on patents. A similar decision was taken with regard to the American aluminium company, Alcoa. Imperial Chemical Industries and Dupont de Nemours were also forced to dissolve their agreement, described as a cartel, and to bring close on 2000 patents into the public domain. In Great Britain the large American firm of Parke Davis Ltd. has been ordered by a court judgment* to grant the licence for a process of manufacturing an antibiotic to its English competitor British Drug House Ltd. Countless other examples of this type could be quoted.

Public opinion today reacts no less strongly against secrets in industry than against secret diplomacy. The leading companies are fully conscious of this fact, and have recently set up 'public relations departments' to make the public aware of their work and their social usefulness. Some of them publish reviews containing not merely the results of scientific research but also technical details which, twenty years ago, would have been regarded as manufacturing secrets. This desire of the larger industrial firms to raise their social prestige is linked with the new trend discernible in business and industry, a trend which has been described as economic humanism.

These developments, however, do not mean that the patent has lost all its value and become an out-dated institution. But it certainly has lost the dominant position it occupied in the business and industrial world only fifty years ago. It is now being superseded by know-how, which is more in line with the technical needs and social outlook of our age.

Everything points to the probability that, in the long run, patents can only retain their legal value and practical utility if coupled with the know-how which is their indispensable corollary.

* *Life*, 26 January 1953, p. 39.

* The Court actually held that the Comptroller-General of Patents was entitled to grant a compulsory licence; but as section 41 (1) of the Patents Act, 1949, imposes an obligation on the Comptroller, on application, to grant a licence of a patent in respect of a substance capable of being used as food or medicine, unless it appears to him that there are good reasons for refusing the application, this in fact meant that a compulsory licence would be granted.

# GEORG SIMON OHM (1780-1854)

HELEN H. BURTON

July 6 is the centenary of the death of Georg Simon Ohm, who gave us a fundamental law of electricity. Although his name is now immortalised in connexion with the fundamental law of electricity, his reputation spread only during the latter part of his life and some years after he had published the classic research results. His early life is one which shows a thirst for knowledge that thrived in spite of the handicap of poverty, unemployment and frustration.

Ohm was born in humble circumstances in the Bavarian town of Erlangen in 1789. His father was a locksmith, yet he had both a wholesome respect for learning and some knowledge of mathematics and philosophy. This led him to give his two sons the best possible education, even though he intended them to follow his own trade. Therefore, with some sacrifice on his own part, he gave both boys a sound schooling and a year's course in mathematics and science at the University of Erlangen. Simon was soon able to maintain himself as a tutor and to save enough money to complete his university course. He took his degree while his country was in the midst of the Napoleonic wars, so he was unable to obtain any academic or tutorial appointment after graduation, and had to return to his father's workshop for six years. During those unhappy years of poverty and privation he pursued his studies as best he could, and at the age of twenty-eight he managed to publish an "Essay on Geometry" which led to his appointment as a teacher of mathematics and physics at the Jesuit High School in Cologne in 1817.

His lectures there were well received, and he soon established a reputation as a very successful teacher. During this period he was well acquainted with the scientific trends in Europe, and for the first time he was able to do some research. Over a hundred years before, van Musschenbroek's experiment of taking a considerable electric shock from a Leyden jar had become all the rage in Europe; in Italy, at the end of the previous century, Galvani made his sensational discovery of 'animal electricity'; in 1800 Volta announced his production of electricity by a pile of plates, and tried to identify it with Galvanic electricity. The advent of methods for producing continuous electricity caused scientific attention to be focused on current electricity in these early years of Ohm's life.

Oersted had recently found a convenient means of detecting and measuring a current, and Ampère was laying the mathematical foundations of electrodynamics. It was Ohm's fortune to investigate the factors which influenced a current passing through metallic conductors.

Ohm's absorbing interest in scientific problems, his persistence learned through hardship and early disappointment, and his skill developed in his father's workshop were factors which enabled him to continue his research with such success. He had only slender means at his disposal, but he was able to make nearly all of his own apparatus with enviable precision and skill. He set about finding out how the current flowing in a conductor varies with the length of the conducting wire, its area of cross-section, and the material of which it is made. He found that the resistance of the wire varied directly with its length and inversely with its sectional area. By taking wires of the same dimensions but of different materials, he drew up a list of specific resistance which, with one exception which he corrected later, stands in the order known today.

In these first experiments he had encountered difficulties with the variations of current given by his batteries, and on the advice of Poggendorf he adopted the thermo-electric circuit discovered a few years earlier by Seebeck. He found a thermocouple made of bismuth and copper, whose junctions could easily be kept at a constant temperature, gave both a steady and adequate current, and he used this with tremendous success in his later experiments. He constructed this copper-bismuth thermocouple in the form of a rectangular brace, the 'legs' of which could dip into the two constant temperature enclosures. The copper arm he incorporated into a torsion balance, and in order to make perfect connexions and ensure precision of length, he used mercury cups to connect the resistance wire under test to the copper of the thermocouple. His torsion balance reduced considerably the personal error in observations, and the consistence of the results he obtained pays tribute to his experimental skill. He soon recognised the fact that his thermo-electric circuit, like his batteries, had a constant internal resistance, and, to distinguish his variable resistance from this, he called the latter the external resistance. At first he kept the same 'electrical pressure' and found how the current varied with the resistance. Then he changed the electromotive force of the thermocouple by maintaining a fresh temperature difference between the junctions. From his results he deduced an expression which can be expressed in modern terms as:

$$\textit{Current in a circuit} = \frac{\textit{Electromotive force}}{\textit{Total resistance}}.$$

These experimental results were published in Schweigger's scientific journal, *Journal für Chemie und Physik* (Vol. 46, p. 137, 1826), but they attracted almost no attention. His later writings of a theoretical nature met with such criticism that he felt bound to resign his appointment at Cologne. It was only in 1841, after years of bitterness and disappointment, that he received the recognition he deserved, and that came from England. Then the Royal Society awarded him the much-coveted Copley Medal, for his outstanding contributions to science. In 1849 he was rewarded by a professorial appointment at Munich University, and in this appointment a lifetime's ambition was fulfilled. In the last years of his life he was able to live as he had always wished, teaching and engaged in research. Content in this walk of life, he died on July 6, 1854, leaving us with a fundamental truth which is the basis of the simple electric circuit.

# CALCULATING MACHINES AND MECHANICAL TRANSLATION

ANDREW D. BOOTH
D.Sc., Ph.D., F.Inst.P.

As far as can be traced, the first suggestion that translation —from foreign language (for which the letters F.L. will afterwards be used as a convenient abbreviation) into a target language (T.L.)—could be achieved by means of a digital calculating machine was made by the present author in 1947. The scheme, as it was then envisaged, merely consisted of using the storage unit of a modern computer to hold the contents of what amounted to a dictionary. This idea was developed in the following years in collaboration with R. H. Richens, and has now emerged as an entirely satisfactory method, at least for the translation of scientific texts.

A number of workers in the U.S.A. have taken up the development of the method and, with their superior resources and the backing of certain U.S. government agencies, they have made considerable progress towards the setting up of installations for the practical application of the method.

The general interest in the matter was shown by the holding—under the auspices of the Rockefeller Foundation—of an international conference on mechanical translation. This took place at the Massachusetts Institute of Technology in June 1952, and a symposium volume, based upon the proceedings, is due to appear in the near future.

It is thus appropriate to set down, briefly, the nature of the machines and the processes involved, and to indicate the possible range of the method.

## MODERN DIGITAL CALCULATORS

Since the operation of a scheme for mechanical translation depends upon techniques which are a part of the modern development of electronic digital computers, it will assist the reader to understand the methods used if a brief account of the relevant features of such machines is given here.

In essence, a computer of the type under discussion consists of four parts:

(i) A unit for performing the operations of arithmetic.
(ii) A control unit for directing the operations of the rest of the machine.
(iii) A store for numbers and instructions (the 'memory').
(iv) Means for inserting data into the machine and for indicating the results of its operations (input/output).

It is not necessary to go into further detail as to the precise functions of these units, except to notice that the store of a modern machine is usually capable of holding many thousands of numbers.

The reader may be under the impression that these machines are necessarily of enormous size and complexity. That this is not the case is shown by the photograph of the A.P.E.R.C.—the All Purpose Electronic Rayon Computer which is working at Birkbeck College, London. This is probably the most compact machine at present in operation, and the extensive planning which went into its design has been amply repaid by the reliable functioning of the installation over long periods; it has, for instance, given 93% faultless operation over a period of 390 hours.

Before leaving the subject of computers, it is necessary to mention that most of these machines work in the so-called binary scale which contains only the digits 0 and 1. It follows that numbers in normal decimal scale have to be represented as binary equivalents, in a manner which will be seen from the following table:

TABLE 1

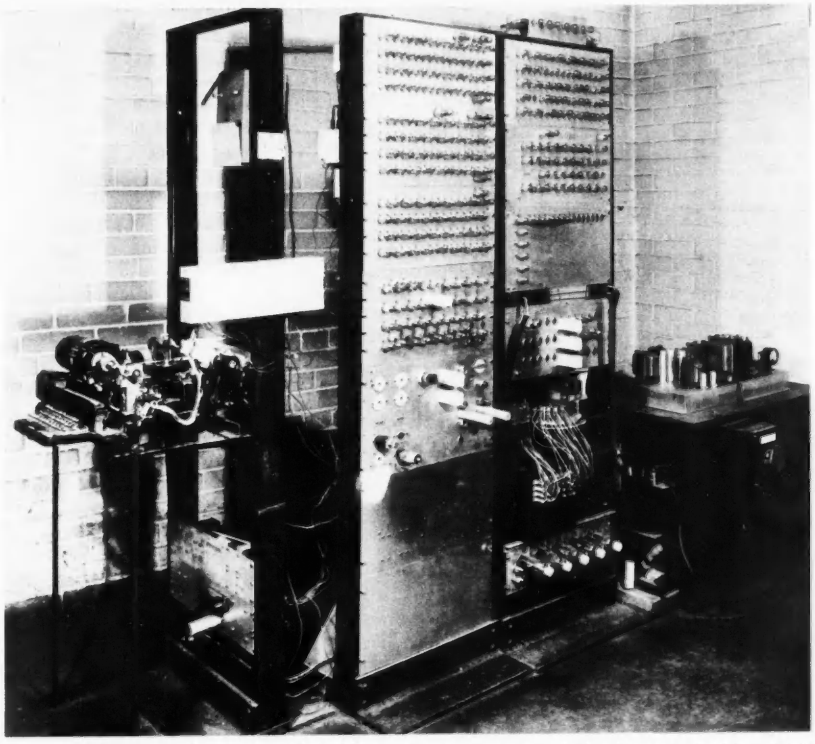
| *Decimal* | *Binary* |
|---|---|
| 0 | 0 |
| 1 | 1 |
| 2 | 10 |
| 3 | 11 |
| 4 | 100 |
| 5 | 101 |
| 6 | 110 |
| 7 | 111 |
| 8 | 1000 |
| etc. | |

## LANGUAGE AND NUMBER

To be able to perform a translation on a computing machine—or indeed on *any* machine—one must be able to represent words by means of numbers. A familiar example of this occurs in the ordinary printing telegraph where the depression of a key on a teleprinter has the effect of transforming the given letter into a stream of electrical impulses, spaced out in time. The international teletype code, for the alphabet, is shown in Table 2, where the symbol ○ indicates an electrical impulse of one type whilst ● is either no impulse at all, or else the negative of ○. It is at once evident that this code is essentially a binary one and that possible 'numerical values' of the various letters are those given in the third column of the table.

TABLE 2. TELETYPE CODE

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | ● | ● | ○ | ○ | ○ | 24 | N | ○ | ○ | ● | ● | ○ | 6 |
| B | ● | ○ | ○ | ● | ● | 19 | O | ○ | ○ | ○ | ● | ● | 3 |
| C | ○ | ● | ● | ● | ○ | 14 | P | ○ | ● | ● | ○ | ● | 13 |
| D | ● | ○ | ○ | ● | ○ | 18 | Q | ● | ● | ● | ○ | ● | 29 |
| E | ● | ○ | ○ | ○ | ○ | 16 | R | ○ | ● | ○ | ● | ○ | 10 |
| F | ● | ○ | ● | ● | ○ | 22 | S | ● | ○ | ● | ○ | ○ | 20 |
| G | ○ | ● | ○ | ● | ● | 11 | T | ○ | ○ | ○ | ○ | ● | 1 |
| H | ○ | ○ | ● | ○ | ● | 5 | U | ● | ● | ● | ○ | ○ | 28 |
| I | ○ | ● | ● | ○ | ○ | 12 | V | ○ | ● | ● | ● | ● | 15 |
| J | ● | ● | ○ | ● | ○ | 26 | W | ● | ● | ○ | ○ | ● | 25 |
| K | ● | ● | ● | ● | ○ | 30 | X | ● | ○ | ● | ● | ● | 23 |
| L | ○ | ● | ○ | ○ | ● | 9 | Y | ● | ○ | ● | ○ | ● | 21 |
| M | ○ | ○ | ● | ● | ● | 7 | Z | ● | ○ | ○ | ○ | ● | 17 |



THE A.P.E.R.C. MACHINE AT LONDON'S BIRKBECK COLLEGE

When a number of keys is depressed in succession the result is the emission of a succession of impulses which, in aggregate, give a number which is characteristic of the word typed, thus:

and = 11000, 00110, 10010 = 24,786

The crudest way in which a calculating machine with storage facilities could perform the operation of translation can now be indicated. Suppose that each storage position* is given a number, then in the storage position bearing the number which represents the word to be translated a further number is placed. This new number gives, in coded form, the translation of the first word. Thus, suppose we are translating English into French; for the word *and*, we find in storage position 24,786, the number 513 or, in binary 10000, 00001. The reader will see, on examination of Table 2, that this represents the letters *et* and by presenting the coded number to a teleprinter the French translation could be printed out.

This simple example serves to demonstrate two things: firstly that translation can be effected by means of an essentially arithmetical machine, and secondly that this particular method is quite impracticable. To emphasise the latter point, it may be remarked that the code numbers of all words of not more than 10 letters would lie in a numerical range whose greatest member is of order $2^{50}$—or about $10^{15}$. No computer storage device is conceivable which has anything approaching this capacity; in any case, the total number of words in any language is probably less than $10^7$ so that only a fraction ($10^{-8}$) of such a store would be occupied.

Fortunately, there are other and more reasonable methods of approaching the problem; one of the simplest is to store the numerically coded form of the F.L. word *and* the code number of the translation in the same storage position. The computing part of the machine now separates off the F.L. digits of each stored word group in turn and compares these, by subtraction, with the digits of the word to be translated. In general, only one of these results will be *zero*, and this corresponds to the correct translation position; modern computers have means of detecting, either directly, or by means of an inserted order sequence, the nullity, or otherwise, of a number so that nothing new is involved. All that remains, is for the machine, having recognised the identity of the F.L. part of a particular entry with the F.L. word to be translated, to output the remainder of the composite entry, which is the required translation.

Even this simplified scheme would require a considerable storage capacity to translate a reasonable proportion of the words occurring in, let us say, a scientific paper, and it was left to Richens to suggest a method which reduced the problem to one well within the capacity of existing machines. This technique will be discussed in the next section, but before leaving the subject of codes for alphabetic characters it is worth mentioning that, for simplicity of

* A modern digital computer has means of storing some thousands of numbers which result from its calculations. These may be likened to the lines on a sheet of paper, and each line is numbered 1, 2, 3 . . . etc. The computer can execute commands of the type "Read the number on line 625" or, "write the answer on line 720".

calculation, the teletype code given in Table 2 has never actually been used in a computer. Instead, the letters are numbered in ascending order of magnitude, thus:

TABLE 3

A = 00001 = 1
B = 00010 = 2
C = 00011 = 3
. . . . . .
Z = 11010 = 26

This is easily arranged on the teleprinter and simplifies considerably the comparison process used in the machine.

## MICRO-SEMANTICS

The practical application of machine translation depends upon two things; firstly that the different words which occur in scientific papers on a given subject are limited in number, and secondly that a simple means exists for dealing with the variants introduced by stem-ending combinations.

Limitation of vocabulary is familiar to anyone who reads specialist papers in a foreign language; thus the set of words required to translate a mathematical paper is quite different from that needed in, say, genetics or brain surgery. Richens and the present author working in this country, and Oswald and Bull (1953) in the U.S.A., have examined this problem, and the conclusion emerges that, to translate a large proportion of the words in a scientific text, some 1000 words of specific scientific application, together with a similar number of words of general literary usage, will suffice. This limited vocabulary has been termed a 'micro-glossary'.

A normal dictionary does not contain an entry for each possible variant of a particular word; thus the word *calculate* will appear, but not *calculates*, *calculating*, *calculated* and so on. Richens has pointed out that by 'storing' the stems and endings in a dictionary separately a much more useful output could be obtained from a small number of entries than would otherwise be the case. For example, the verb stems:

calculat-
differentiat-
lov-
mat-
not-
releas-
teas-
undulat-
violat-
wak-

can all take the common endings *-e*, *-es*, *-ing* *-ed* when used as verbs, the endings *-er* and *-or* when used as nouns and so on. Thus by storing stems and endings separately in the cases just quoted, 10 stems and 6 endings would enable 50 to 60 different complete words to be translated.

The way in which this is put to use in a calculating machine, or other mechanical translator is as follows: the complete F.L. word is first coded into binary numerical form. The number thus resulting is then compared, by subtraction, with the F.L. part of each dictionary entry; starting with that part of the dictionary which contains complete words. It may so happen that the exact entry is found, in which case the translation is produced at once; if, on the other hand, no exact equivalent is present, one letter (or more accurately the group of digits representing one letter) is removed from the end of the F.L. text word and the process is repeated. In this way a point will be reached at which the longest portion of the text word, corresponding to a stem entry in the 'dictionary', is found. When this occurs the stem translation is printed out, and the letters (in coded form) which have been removed are examined by comparison with the ending dictionary contents. The result of this final comparison then appears as 'grammatical notes' in which, for example, the person and tense of verbs are indicated.

This description gives, of course, a simplified picture of the complete process that is needed to ensure translation of the multiple words in a language such as German, and to take care of multiple word units such as *a-t-il* and *ne . . . pas* in French, but it should help the reader to grasp the general manner in which an essentially arithmetic machine can deal with a problem which, at first sight, appears to have little to do with calculation.

It may be of interest to see three specimens of the sort of output which is produced by such mechanical translation. The first is a translation of an Italian piece from the literature of plant genetics.

*Original passage in Italian*

E' stato prov/ato che i cereal i d'invern /o cresc/iuti in serra mostr/ano poc/a resistenza al freddo, mentre gli stessi cresc/iuti in campo apert/o, sono molto/o più resistent/i.

*Machine output*

is (been / status) prove (p) (that / which) (v) cereal (m) of winter (z) grow (pm) in (mountain / crowd / greenhouse) show (m) little (v) resistance to cold while (v) same (m) is (ps) grown (pm) in field open (v) are much (v) more resistant (m).

*English translation*

It has been proved that winter cereals grown under glass show little resistance to cold, while those grown in the open are much more resistant.

It should be noticed that the grammatical notes supplied by the machine are:

(m) = multiple or plural
(p) = past
(s) = subjective
(v) = vacuous, i.e. having no English significance
(z) = unspecific
/ = stem-ending separation point.

The second example shows the result of supplying a message in Russian to the I.B.M. '701' data processing machine. Some of the stages involved are shown opposite in Table 4.

# TABLE 4

## How the passage is analysed

| RUSSIAN WORD | ENGLISH EQUIVALENTS I | II | 1st CODE | 2nd CODE | 3rd CODE | RULE NO. |
|---|---|---|---|---|---|---|
| vyelyichyina | magnitude | — — — | *** | *** | ** | 6 |
| ugl- | coal | angle | 121 | *** | 25 | 2 |
| -a | of | — — — | 131 | 222 | 25 | 3 |
| opryedyelyayetsya | is determined | — — — | *** | *** | ** | 6 |
| otnoshyenyi- | relation | the relation | 151 | *** | ** | 5 |
| -yem | by | — — — | 131 | *** | ** | 3 |
| dylin- | length | — — — | *** | *** | ** | 6 |
| -i | of | — — — | 131 | *** | 25 | 3 |
| dug- | arc | — — — | *** | *** | ** | 6 |
| -i | of | — — — | 131 | *** | 25 | 3 |
| k | to | for | 121 | *** | 23 | 2 |
| radyius- | radius | — — — | *** | 221 | ** | 6 |
| -u | to | — — — | 131 | *** | ** | 3 |

*What the Rules mean:*

RULE 1:

REARRANGEMENT

If the first code is 110, is the third code associated with the preceding complete word equal to 21? If so, reverse the order of appearance of the words in the output (i.e. a word carrying 21 should follow one carrying 110)—otherwise, retain the order.

In both cases, English equivalent I associated with 110 is adopted.

RULE 2:

CHOICE, FOLLOWING TEXT

If the first code is 121, is the second code of the following complete, subdivided or partial (root or ending) word equal to 221 or 222? If it is 221, adopt the English equivalent I of the word carrying 121. If it is 222, adopt English equivalent II.

In both cases, retain the order of appearance of the output words.

RULE 3:

CHOICE, REARRANGEMENT

If the first code is 131, is the third code of the preceding word or either portion (root or ending) of the preceding subdivided word equal to 23? If so, adopt English equivalent II of the word carrying 131 and retain the order of words in the output. If not, adopt English equivalent I and reverse the order of appearance of words in the output.

RULE 4:

CHOICE, PREVIOUS TEXT

If the first code is 141, is the second code of the preceding complete word or either portion (root or ending) of a preceding subdivided word equal to 241 or 242? If it is 241, adopt the English equivalent I of the word carrying 141. If it is 242, adopt English equivalent II.

In both cases, retain the order of appearance of words in output.

RULE 5:

CHOICE, OMISSION

If the first code is 151, is the third code of the following complete word, or either portion (root or ending) of the following subdivided word equal to 25? If so, adopt English equivalent II of the word carrying 151. If not, English equivalent I.

In both cases, retain the order of appearance of words in the output.

RULE 6:

SUBDIVISION

If the first code associated with a Russian dictionary word is . . . then adopt English equivalent I of alternative English language equivalents, retaining the order of appearance of the output with respect to the previous word.

*Original passage in Russian*

Vyelyichyina ugla opryedyelyayetsa otnoshyenyiyem dlyini dugi k radyiusu.

The message is punched upon a card and processed in various pieces of equipment shown in Fig. 2. Eventually the output—"Magnitude of angle is determined by relation of length of arc to radius"—appears on the typewriter. This particular system was evolved by Dr. Leon Dostert, who appears as the central figure in the fourth photograph on p. 284.

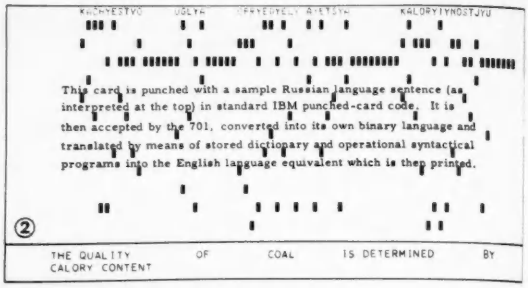
As a final example, the following short passage (from a German text on neurosurgery) is the result of the application of a statistical-frequency analysis to the word forms contained in a selection of the literature. It is quoted from one of the most recent reports of Oswald and Lawson (1953) who have been studying the application of the Institute for Numerical Analysis Computer to the problem.

*Original Text in German*

Die Verletzungen im Bereich der vorderen Schördelbasis stellen den Chirurgen immer wieder vor die Frage, in welcher Form derartige Verletzungen wegen der möglichen Beteiligung der Nasennebenhöhlen (NNH) am besten zu versorgen sind. Hierbei spielt die Drainage des NNH—Gebietes eine wichtige Rolle.

*Machine output*

The injuries in-the region of-the anterior cranium base put the surgeon always again before the question, in


This card is punched with a sample Russian language sentence (as interpreted at the top) in standard IBM punched-card code. It is then accepted by the 701, converted into its own binary language and translated by means of stored dictionary and operational syntactical programs into the English language equivalent which is then printed.
THE QUALITY OF COAL IS DETERMINED BY CALORY CONTENT

The Type '701' electronic data-processing machine of International Business Machines Corporation translating from Russian into English.
1. The typist prepares a punched card. 2. Specimen punched card, and below it a strip with the translation. 3. General view of the machine. In the centre of the units shown is the Electronic Analytical Control Unit, and at its right is a Card Reader; behind the control unit is the Power Distribution Unit. On the left are the Magnetic Drum Storage Unit and the Electrostatic Storage Unit. In the right-hand group are two Magnetic Tape Readers and Recorders, the Alphabetical and Numerical Printer and the Card Punch. 4. Dr. Leon Dostert (*centre*), chairman of Georgetown University's Institute of Languages and Linguistics, looking at continuous sheet of English-worded sentences coming from the printing mechanism. 5. Sheet of English-worded sentences produced by the printing unit of the '701'.

which form such injuries on-account of the possible participation of-the nose sinuses (NNH) at the best to treat are. Here plays the drainage of the NNH. —area an important role.

*English*

Injuries of the base of the anterior cranium, always place before the surgeon the question of the best treatment, in view of the possible participation of the nasal sinuses. The drainage of the nasal sinus area here plays an important part.

## FUTURE PROSPECTS

Several important obstacles still remain to be overcome in the field of mechanical translation. First is the need for an adequately fast input and output for the machine; this is obvious when one considers that the translation of a 1000-word text by machine takes between 2 and 7 hours with currently available facilities, which is considerably longer than the time required by a skilled human translator. Two attractive possibilities exist for improving this situation; in the first a scanning device 'reads' the actual text or typescript to be translated; in the second the machine operates from a spoken input. Both of these suggestions are at present under investigation, the first by D. Shepherd and his group in the United States, and the second at Bell Laboratories and also at Birkbeck College. The problem of output is not so critical as a number of high-speed printers are already available. Even with the present limitations the process is still useful, since a range of foreign languages can be translated with the same equipment, whereas few laboratories would have a 'range' of multilingual humans.

A second need is for the construction of a special machine for mechanical translation since although a general-purpose digital computer can perform the operations, it is too complex in the arithmetic sense and too small in the size and quantity of the numbers of words which it can store. As an indication of the sort of thing meant, a typical existing computer 4 can store 1024 'words' each of 32 binary digits and can perform the operations of $+$, $-$, $\times$, and shift, whereas what is required is a machine with storage for 4000–8000 'words' of 250 binary digits and an arithmetic unit which need only subtract and shift.

On the linguistic side much remains to be done; adequate microglossaries do not exist—or at any rate are not generally available—and, it will be some time before really comprehensive stem-ending compilations are ready. It may be that the suggestion of E. Reiffler (1952) of pre-editors and post-editors will prove necessary. The pre-editor, a native in the F.L. who need not have any knowledge of the T.L., removes syntactic and morphological ambiguities from the original text, whereas the post-editor renders the machine output into respectable English (or, of course, any other T.L.). Yet again, it is possible that the suggestion of Dodd (1952) for universal scientific publication in some standardised literary form may find favour.

This field is an expanding one, in which new ideas both linguistic and engineering are constantly arising. If we cannot, at present, translate by machine the German of Goethe into the English of Wordsworth, it is by no means certain that this will be true in five or ten years' time.

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# SIR CHARLES PARSONS (1854–1931)

This year is the centenary of Sir Charles Algernon Parsons, who ranks next in succession to James Watt in the history of prime movers. As one American writer puts it, "He foresaw the coming age of electricity, and succeeded because he was able to combine the steam turbine and the dynamo."

He was born on June 13, 1854. His father, the third Earl of Rosse, who was a distinguished astronomer, had a well-equipped workshop in which he constructed telescopes and other equipment, and there his son acquired his skill as a mechanic. After studying at the universities of Dublin and Cambridge (for his marks in mathematics he was ranked as eleventh Wrangler at Cambridge), he joined the Armstrong Works at Elswick as an apprentice. While a partner in the firm of Clarke, Chapman & Co. of Gateshead he began experiments which culminated in the construction of his first turbine (1884). Just a short time before Dr. Laval of Sweden had invented a steam turbine, but it is fair to say that "it was Parsons's invention of 1884 of the compound steam turbine applied to the direct driving of dynamos that proved most successful of all such contemporary inventions". The turbine came to rival the reciprocating engine in efficiency, and was adopted very speedily for the generation of electricity in large central power stations. By 1912 turbo-generators with a power of 25,000 kilowatts (33,000 horse-power) had been constructed.

Very soon the steam turbine was applied to ship propulsion. Parsons's turbine ship, the *Turbinia*, literally made rings round the fastest destroyers of the British Fleet in 1897, reaching a speed of 34 knots. In 1905 the British Navy decided that henceforth all new warships it ordered should be driven by turbines. The first merchant vessel driven by turbine was built in 1901. Within a few years turbines were driving such huge vessels as the *Mauretania* and *Lusitania*, each of which had four turbines totalling 70,000 horse-power.

In 1889 he founded the firm of C. A. Parsons & Co. at Heaton near Newcastle upon Tyne where he produced parabolic reflectors. Optics increasingly engaged his attention, and he took over the Derby Crown Glass Works.

His pioneer work on turbines has been well described in DISCOVERY (March 1944) by R. H. Parsons.

# GROWING ROOTS WITHOUT PLANTS

DR. H. E. STREET

*The researches described in this article have been done at Manchester University by the team directed by Dr. Street, who has just been appointed Botany Professor at Swansea.*

As early as 1902 Gotlieb Haberlandt suggested that the culture of isolated cells or tissues would lead to important additions to our knowledge of the synthetic ability of cells, and of their nutritive inter-relationships in muticellular plants. There followed a series of attempts to culture *mature* cells which had been isolated from flowering plants, but in all cases the cells remained alive for only a short time and failed to divide. Exploitation of the idea postulated by Haberlandt only proved possible when attention was directed to the culture of cells in an active state of division—cells from the growing regions or meristems of the plant.

Progress has now been made along two main lines:

(*a*) the culture of isolated root tips (*excised root culture*).
(*b*) the culture of the dividing cells which increase the girth of plants (*cambium culture*).

This article will describe the technique of excised root culture in its present form, and then proceed to consider briefly those aspects of plant physiology in which its use has already advanced knowledge or is likely to do so in the immediate future.

In 1922, W. Kotte at Grotzingen and W. J. Robbins working at the New York Botanic Garden showed that when root tips of certain plants were detached (plant physiologists use the term *excised*) and transferred to a culture medium containing glucose, mineral salts and a complex organic supplement (e.g. Liebig meat extract or yeast extract) they grew into normal roots.

Robbins also demonstrated that root tips excised from such cultured roots were capable of further growth when they were transferred to fresh culture medium. However, at each repetition of this procedure *subculture*, the growth rate declined until ultimately the cultures stopped growing altogether and died. In 1934, P. R. White of the Rockefeller Institute for Medical Research, using a similar culture medium but with *sucrose* instead of glucose as the carbohydrate source, succeeded in subculturing excised tomato roots without any diminution of their growth rate, and from a single root tip he succeeded in establishing a clone[1] in continuous culture. By 1937 White had shown that this continuous culture of excised tomato roots was possible in a medium in which the yeast extract was replaced by pure aneurin (vitamin $B_1$). His demonstration that excised tomato roots could be continuously cultured in a medium of known composition represented an outstanding technical achievement which has been the model for all subsequent work in this field.

## THE TECHNIQUE OF EXCISED ROOT CULTURE

Excised roots can be taken from seedling roots, or from the adventitious roots that develop on cuttings or storage organs, such as bulbs and tubers. It is essential to obtain root tips that are uncontaminated with micro-organisms since the medium required for root growth is also capable of supporting the growth of many moulds, yeasts and bacteria. It is not yet possible to use root tips from ordinary growing plants just because no satisfactory method has yet been devised to surface-sterilise root tips without damaging their living cells. On the other hand, *adventitious*[2] roots developing rapidly in a sterile, moist atmosphere have been found to yield a proportion of uncontaminated tips. Sterile seedling roots can be readily obtained by surface-sterilisation of seeds with bromine water or hypochlorite solution followed by germination in sterile petri dishes containing moist filter paper (Fig. 1). When the seedling root is 20–40 millimetres long the apical 10 millimetres is excised with a sterile scalpel and the tip transferred aseptically (i.e. taking precautions to avoid contamination) to sterile culture medium.

The initial transfer of tips to culture medium (and the subsequent subculturing) should be carried out under a mycologist's glass screen; better still these operations should be performed in a sterile transfer-room, particularly where large numbers of cultures are being established. At Manchester University, sterile transfer rooms (Figs. 2 & 3) are used in which there is maintained a positive pressure of air that has been sterilised by passage through a bacterial filter; the internal surfaces of the room and the external surfaces of the glassware and operator are initially sterilised by a short exposure to ultra-violet radiation. The requisite instruments, which include fine-pointed stainless steel scissors for excising the root tips and platinum loops for their transfer, are kept sterile in a beaker of boiling distilled water.

The basic culture media used in root culture work contain sugar (usually sucrose), a mixture of inorganic salts and a mixture of B-vitamins. The standard culture medium used at Manchester University is a modification of White's synthetic medium (see Table 1).

The experimental culture media used in these physiological studies are variations of this standard medium. The medium is modified: (*a*) by omitting (or changing the concentration of) its individual constituents; (*b*) by changing its hydrogen-ion concentration (*p*H); or (*c*) by addition of compounds whose effect on growth is to be studied. The medium is distributed to the culture flasks and then sterilised, usually by autoclaving at 15 lb. steam pressure for 5 minutes. When a batch of culture medium contains substances which are unstable to heat, sterilisation of the whole medium, or of the thermolabile material alone, is achieved by filtration through sintered-glass filters fine enough to prevent the passage of micro-organisms. Where only the thermolabile fraction is thus sterilised by filtration, this is subsequently added aseptically to the remainder of the medium which has been previously sterilised by autoclaving (Fig. 3). The culture vessels used for routine work are 100-millilitre Pyrex wide-mouthed

[1] Roots, all of which are devised from the root of a single seedling.

[2] Roots developed from a stem or leaf as distinct from roots arising by branching of the root system.

TABLE I

*Composition of Standard culture medium*

| | as anhydrous compound |
|---|---|
| Sucrose | 20 grams |
| Calcium nitrate | 200 milligrams |
| Magnesium sulphate | 360 ,, |
| Potassium nitrate | 80 ,, |
| Potassium chloride | 65 ,, |
| Sodium sulphate | 200 ,, |
| Sodium dihydrogen phosphate | 16·5 ,, |
| Potassium iodide | 0·75 ,, |
| Manganese chloride | 4·5 ,, |
| Zinc sulphate | 1·5 ,, |
| Boric acid | 1·5 ,, |
| Molybdic acid | 0·0017 ,, |
| Copper sulphate | 0·013 ,, |
| Ferric sulphate | 2·5 ,, |
| Aneurin hydrochloride | 0·1 ,, |
| Pyridoxine hydrochloride | 0·1 ,, |
| Nicotinic acid | 0·5 ,, |
| Glycine | 3·0 ,, |
| Water (twice distilled from Pyrex glass) to make up | 1 litre of culture medium |

conical flasks. Each flask contains 50 millilitres of culture solution and is closed with a plug of non-absorbent cotton wool enclosed in cotton gauze and covered with an inverted Pyrex beaker (Fig. 4). A special form of closure, using a collar of cotton wool, has been developed for use when the micro-element or vitamin requirement is being investigated (Fig. 5); this ensures that no particles of cotton wool can drop into the medium, and that any condensation

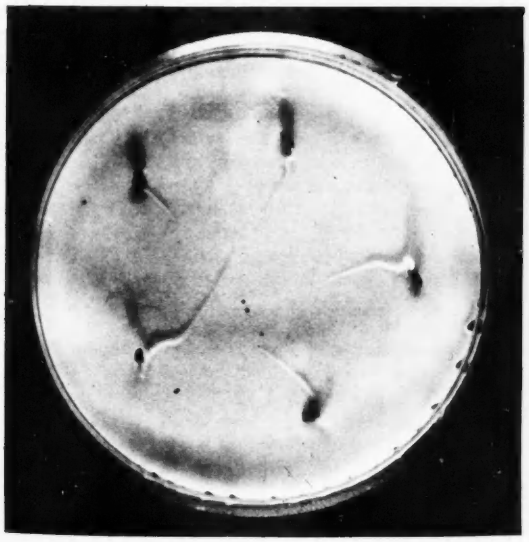
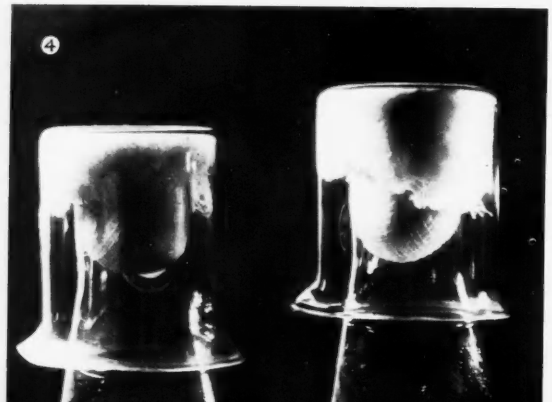
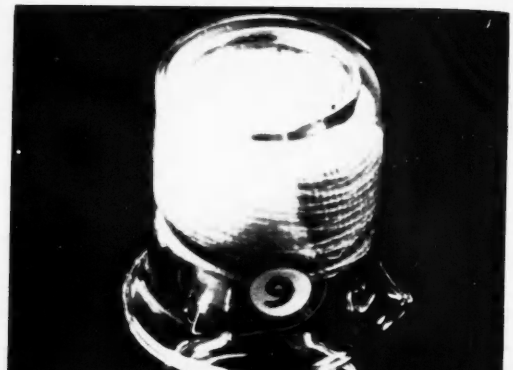


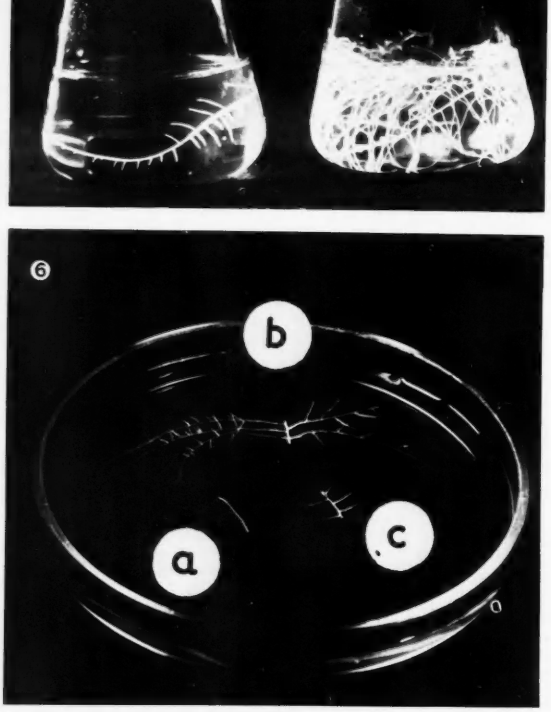
FIG. 1. Sterile tomato seeds germinating on moist filter paper under aseptic conditions. The seedling roots are at the stage when their tips are excised for culture.

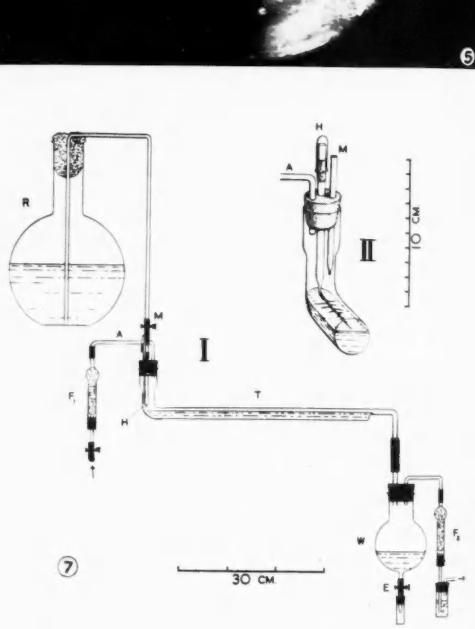
FIG. 2. Subculture of excised roots being carried out in a sterile transfer room. The operator is excising root tips. These will subsequently be transferred to the flasks of media. The beaker of boiling water used to maintain the instruments sterile is shown on the left.

FIG. 3. Sterilisation of thermolabile material by filtration. The filtering apparatus is shown held on two retort stands. To the right is the Buchner type sintered glass filter through which the liquid to be sterilised has been drawn by vacuum and collected in the round-bottom flask. The sterile solution is now being measured out in the graduated burette to the left and transferred aseptically to the culture flasks. The whole operation is being carried out in the sterile transfer room. The top light is an ultra-violet light (wavelength 2537 Å).







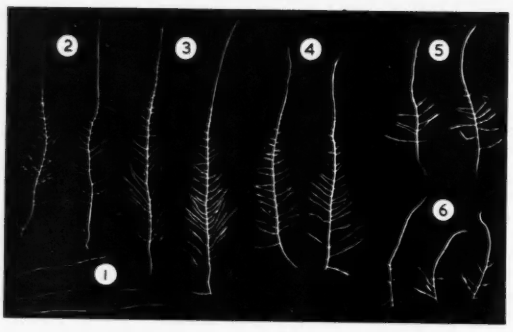




FIG. 4. Excised tomato roots grown for 21 days in 50 ml. of culture medium. The flask on the left contains standard medium, that on the right a medium in which ferric citrate has been substituted for the ferric sulphate of standard medium. FIG. 5. Culture flask showing the closure used in vitamin-requirement and micro-element work. FIG. 6. Petri dish containing: *a* a 10-mm. root tip excised from the 7-day sector culture (*b*). This tip can be used to start a tip culture; *c* a portion of the main axis of a 7-day tip culture suitable to start a sector culture. FIG. 7. Apparatus used to grow excised roots in continuously flowing culture medium. I. the complete apparatus showing the reservoir of medium (R), the culture tube (T) and the waste receiver (W). II. detail of the apex of the culture tube showing the root holder (H) with young root in position, the medium entry tube (M) and the aeration tube (A). FIG. 8. Excised tomato roots grown in different concentrations of sucrose. *1* 0·5%; *2* 1·0%; *3* 1·5%; *4* 2%; *5* 3%; *6* 4%.

water which falls back into the medium has only been in contact with Pyrex glass.

To start a batch of root cultures, flasks of sterile medium are inoculated with single root tips and then incubated at a suitable controlled temperature (e.g. 27° C) usually for a week. With excised roots of tomato, and of a number of other species, subculture can then be effected either by excising the apical 10 millimetres of the main axis (main axis tip) or by excising a portion (a sector) of the main axis bearing 4–6 young laterals (Fig. 6). These sectors after seven days' growth (Fig. 6) will yield 4–6 root tips from the primary lateral branches that develop and also further sectors (in this case portions of the primary laterals bearing young second order laterals). Sector cultures therefore not only act as a source of root tips for experimental cultures (tip cultures) but also enable a clone of excised roots to be built up from a single seedling root tip. Excised roots of some species (e.g. pea) do not readily form lateral roots in culture. In such cases roots can only be subcultured by excising the main axis tip, and clones cannot be built up.

The growth made by the experimental tip cultures, usually after seven days' incubation, is assessed by measuring the individual roots,* and by fresh and dry weight determinations. The harvest of roots can also be used for anatomical, cytological and chemical investigations. Each experimental treatment is usually represented by not less than ten replicate cultures.

In certain investigations it is desirable to grow excised roots, without subculture, for longer periods than is possible using the standard culture flasks. In such cases large penicillin-culture flasks or a special apparatus giving a continuous flow of medium have been employed; Fig. 7 shows an apparatus of this type which was developed at Manchester in collaboration with E. H. Roberts. With apparatus of this type, or where it is desirable to make daily estimates of linear growth without disturbing the cultures, incubation is best carried out in a temperature-controlled room in which a positive pressure of filtered air is maintained.

The standard medium becomes less acid as the roots grow in it; a drift from *p*H 4·6 to *p*H 5·6 is normal. By about the fifth day of incubation, this drift causes precipitation of the iron present in the culture solution, and the growth rate of the roots then decreases due to iron deficiency. This precipitation of iron can be prevented† by replacing the ferric sulphate of standard medium by ferric citrate or ferric ethylenediamine tetra-acetate (FeEDTA for short). In media containing FeEDTA it is possible to prevent the alkaline drift and to stabilise the *p*H over a wide range (*p*H 4·0–8·0) by using as buffers either sodium mono- and dihydrogen phosphate mixtures, or by using mixtures of calcium carbonate and calcium phosphates. By using FeEDTA, the above buffer methods and by modification of the nitrogen supply it is now possible to obtain high rates of excised root growth over the *p*H range 4·0–7·5. These technical modifications, which were worked out in collaboration with Dr. M. McGonagle and D. G. Sheat, have made it possible, for the first time, to study the effects of *p*H on the absorption and physiological activity of substances affecting excised root growth.

## APPLICATIONS OF THE TECHNIQUE IN PHYSIOLOGICAL RESEARCH

Excised roots have the normal morphology and anatomy of seedling roots* and both of these depend upon the species, variety or genetic strain of the plant from which they are derived. Although each clone of roots has its characteristic morphology, this depends upon the culture conditions—including the composition of culture medium and physical conditions, e.g. temperature, light, oxygen tension—during growth. For instance, marked changes in such features as the frequency of laterals, root diameter and size of the meristems result from changes in the sugar concentration of the medium (Fig. 8) or from additions of plant growth hormones (auxins). In general, excised roots do not regenerate shoots. Recently, however, Drs. Norton and Boll† have obtained a clone of *Lycopersicon peruvianum* in which shoot buds arise in the callus tissue[3] which normally forms to a greater or less extent at the cut surface of excised root tips. The formation of these buds was initiated by growth on a solid culture medium which contained the leaf-growth factor called adenine. The conditions which induce or suppress such shoot buds have now to be worked out. Exploitation of excised root cultures for study of the factors which determine the origin and form of plant structures—i.e. their morphogenesis—is in its infancy.

This work on bud initiation may have a further important consequence. If buds can be induced at will on excised roots, it will be possible to take clones differing markedly in growth habit and/or physiological response, and to raise plants from them. Controlled crossing between such plants may yield progeny whose roots can be cultured and compared with those of the parent clones. Marked differences in growth rate and morphology between separate clones derived from inbred plants, and even more so between clones derived from geographic strains within species, have already been demonstrated. Control of bud initiation in such material would clearly facilitate attempts being made with excised root cultures to open up studies in the biochemical genetics of higher plants.

The technique of excised root culture enables the roots of a number of species to be successfully maintained in culture. *However, it is not yet possible to culture all species, or even all strains within a species.* White, for instance, was only able to culture the roots of nineteen out of the thirty-one dicotyledonous species he tested. Almestrand, Bonner and others have attempted, but without success, to culture the roots of monocotyledonous species. Two possible

* It is customary to record the following details: the increase in length of the main root axis; the number of laterals per root; the total length of laterals per root.

† Street, H. E., Moira P. McGonagle and Sheila M. McGregor, *Physiologia Plantarum*, 1952, Vol. 5, p. 248.

* No normal secondary thickening takes place even in the extensive root systems which can be grown using large volumes of medium. However, irregular cell divisions frequently take place in the stele and additional xylem vessels arise in this secondary tissue to an extent controlled by the carbohydrate status of the roots.

† Norton, J. and Boll, W. G., *Science*, 1954, Vol. 119, p. 22.

[3] Tissue formed by cell divisions initiated in response to wounding (in this case the excision cut).

explanations of our present inability to culture the roots of many species are:

(1) A requirement for some growth factor(s) or metabolite(s) not supplied or supplied under unsuitable conditions by root culture media hitherto used (complex growth supplements such as leaf and endosperm extracts which have proved ineffective may contain the required compounds but have an over-riding toxicity due to other compounds they contain).

(2) A derangement of root metabolism, resulting from detachment from the shoot and causing the accumulation of lethal substances within the root—this implies some influence of the shoot which cannot ever be supplied by the culture media for otherwise it becomes identical with (1) above.

Frequently the initial growth in culture is good but declines with each subculture and ultimately growth ceases. Some recent work at Manchester points to the absence of essential compounds from the medium as the cause of this progressive decline in growth on subculture. Work with roots of the common groundsel (*Senecio vulgaris*) showed that the growth of roots of certain strains was markedly stimulated by the addition of ornithine-cycle amino-acids[4] to the standard medium and more recent unpublished work indicates that other strains may be limited in growth by the absence of still other amino-acids. E. H. Roberts has now successfully cultured clones of rye-roots and shown them to have an absolute requirement for some substance(s) supplied by 'Difco' yeast extract (Fig. 9). Work designed to identify the active material is, in this case, now well advanced and points to a single active substance. This work on culturability—on the composition of media required to support the growth of excised roots of different species and different strains within a species—illustrates a unique contribution of the technique to plant physiology. It enables us to study the synthetic ability of roots; we can find out how far root growth is dependent upon organic materials synthesised in the shoot, and to what extent this nutritional relationship varies within and between species. The culture of excised tomato roots shows that their only indispensable organic requirements are supplies of *utilisable carbohydrate* and of *aneurin*, both of which are known to be synthesised in green leaves. Most clones of excised tomato roots are, however, markedly stimulated by supplying in addition pyridoxine and nicotinic acid, which probably indicates that a low rate of synthesis of these vitamins by the root is normally supplemented by supplies from the shoot. This conclusion is supported by the persistent presence of small amounts of these substances in roots repeatedly subcultured in their absence. Bonner and his collaborators,* working at the Kerckoff Laboratories of the California Institute of Technology, have examined in detail the requirements of excised roots of a number of species for the B-vitamins. They found that roots of flax could be maintained in culture in the complete absence of B-vitamins although their growth was markedly stimulated by aneurin. White clover roots also had no absolute requirement for aneurin. When aneurin was supplied, the roots of various species differed in their responses to pyridoxine and nicotinic acid. In some cases pyridoxine, in other cases nicotinic acid and in one case (*Stramonium*) both of these vitamins were essential for continuous culture. In those cases where the essential vitamin requirements were aneurin *plus* either nicotinic acid or pyridoxine, then the roots differed in their response to the inessential vitamin: in some cases it was without effect, in other cases it had a markedly stimulatory action on growth. These researches of Bonner well illustrate the differences in the requirements of excised roots of different species for the individual B-vitamins of the standard culture medium (aneurin, pyridoxine and nicotinic acid). This brings us back to the question of biochemical genetics, for when clones differing in their requirements for organic substances are derived from within a species or from interfertile species, then it should be possible to explore the genetical control of certain pathways in root metabolism.

It has proved possible to maintain clones of excised tomato roots in culture without any loss of growth vigour over a very long period. This can only be achieved by growing new *lateral* root tips. These root tips are apical growing points (centres of cell division or meristems). If instead, individual meristems are repeatedly subcultured —i.e. the roots are maintained by repeated excision and growth of their *main axis* tips—then each meristem proves to have a limited life span. During the first few subcultures the meristem develops to its full size and root growth increases; subsequently growth declines and individual meristems begin to die. Study of individual meristems from this point onwards shows that their activity alternately declines (i.e. there is an 'ageing' effect) and rises ('rejuvenation'), and that complete loss of activity is likely to occur during any phase of declining activity. If instead of repeated subculturing, the root is allowed to grow on in a large volume of medium (or in medium which is continuously renewed), then eventually the meristem of the main axis becomes non-functional and the further growth of the root system is carried on by the more recently initiated lateral meristems. The activity of a meristem is prolonged, but not indefinitely, by excising it periodically from the root system to which it has given rise. Its activity is also enhanced by low-intensity illumination of the cultures, but by contrast it is reduced by increasing the sugar concentration of the medium. Observations of this kind show that the apical meristems of excised roots may exhibit 'physiological ageing'. Study of the factors which control the meristematic activity of excised roots indicates that their 'physiological ageing' is probably caused by critical changes in the hormonal balance within the meristem.*

To explain these results the hypothesis has been advanced that cell division in the apical meristem is controlled by a hormone, which at low concentration stimulates, and at high concentration inhibits, growth. When this hormone reaches a critically high concentration it causes irreversible loss of

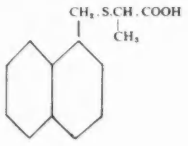
[4] The amino-acids involved in the stepwise formation of urea i.e. ornithine, citrulline, arginine or their precursors (see Skinner, J. C. and H. E. Street, in *The New Phytologist* 1954, Vol. 53. p. 44.)

* Bonner, J. and Bonner, H. "The B vitamins as Plant Hormones", *Vitamins and Hormones*, 1948, Vol. 6, p. 225.

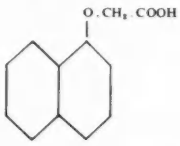
* Street, H. E., *Physiologia Plantarum*, 1954, Vol. 7. p. 212; *Nature*, 1954, Vol. 173, p. 253.

the capacity of the cells to divide, and the root tip ceases to function as a growing point. Newly initiated lateral meristems contain a low concentration of hormone; this concentration rises as the root grows. The activity and size of the meristem increases until the concentration of hormone becomes optimal. Further accumulation of hormone leads to growth inhibition and ultimately to complete loss of meristematic activity in the root tip. This accumulation is accentuated by raising the sucrose concentration of the medium; decreased by exposing the growing roots to light. It is interrupted by separating the meristem from the older parts of the root (i.e. by subculturing the main axis tip); hence this procedure prolongs the life of the root tip.

This hypothesis is supported by observing the response of the roots to substances (anti-auxins) whose physiological activity is thought to arise from their counteracting the action of natural growth hormones (auxins). The two anti-auxins used were α-(1-naphthylmethylsulphide)-propionic acid (NMSP) and 1-naphthoxyacetic acid (1-NOA)




NMSP




1-NOA

These substances even at very low concentrations inhibit the growth of newly initiated lateral meristems, but stimulate the growth of the main axis of the root. With increase in the concentration of anti-auxin there is progressive stimulation of the activity of the main root tip, this reaches an optimum and then further increase in concentration causes inhibition. If the roots are grown in meditum of high sucrose content or if 'aged' root tips are tested then a higher concentration of the anti-auxins is required to obtain maximum growth stimulation. Whenever the growth conditions are such as to cause the hormone concentration in the root tips to exceed its optimum value then appropriate treatment with anti-auxins enhances root growth by neutralising the effect of the excess hormone. Therefore, as expected from the hypothesis, appropriate treatment with these anti-auxins will increase survival of activity in meristems repeatedly subcultured, or prolong the duration of growth of the main axis in roots allowed to grow on in large volumes of medium. Neither of the anti-auxins will counteract the inhibition of root growth caused by externally applied β-indolylacetic acid. From this and other observations the tentative conclusion has been reached that the hormone controlling cell division in the growing root tip is an auxin-like substance but is not β-indolylacetic acid. This investigation of 'ageing' in excised roots may be expected to contribute to our understanding of apical dominance, of the 'ageing' of whole plants and of the role of hormones in the phenomena.

The technique of excised root culture is also proving of value in the study of more restricted aspects of cell growth and metabolism. Excised roots respond in a characteristic and reproducible manner to externally applied auxins. The effects of β-indolylacetic acid and of β-indolylacetonitrile on cell division and cell expansion (the two processes responsible for root growth) is the subject of current investigation.* This work indicates the possible value of excised root clones in the assay of auxins and growth inhibitors, particularly where effects on cell division are being studied.

Whenever the carbohydrate requirement of excised dicotyledonous roots has been investigated they have been found to have a specific requirement for cane-sugar (sucrose). No other sugars will substitute effectively, not even a mixture of its constituent monosaccharides, glucose and fructose. Study of the conditions controlling the utilisation of sucrose points to a mechanism of absorption which involves a phosphorolytic splitting of the disaccharide.† This work may be important in understanding the mechanism of sugar transport within the plant. Some natural sugars, even at low concentrations, markedly exhibit the growth of excised roots; in the cases of galactose and mannose this toxicity is antagonised by glucose (Fig. 10). Study of these antagonisms is now being actively pursued in the hope that it will contribute to our inadequate knowledge of the biochemical inter-relationships between sugars. Similarly, some amino-acids are markedly toxic to root growth,‡ and this toxicity can often be neutralised by the simultaneous application of other amino-acids. The most marked cases of antagonism found involve pairs of amino-acids of similar chemical structure. Excised roots, growing as they are under sterile conditions, are very suitable for investigations of the mechanism of these amino-acid antagonisms.

The requirements of excised roots for the B-vitamins enable us to study the physiological and cytochemical effects of vitamin deficiencies. Study of the effects of the composition of the medium on the growth response to added vitamins and on the limiting concentrations at which they are fully effective can yield interesting problems in vitamin metabolism. For instance, in some strains of excised tomato roots the pyridoxine requirement can be almost completely replaced by supplying the amino-acid glycine. Study of the mechanism of this replacement, now being undertaken in the University of Texas, should increase our understanding of the functioning of pyridoxine in metabolism. Excised roots, though unable to synthesise some of the B-vitamins, are active centres for the synthesis of certain other vitamins of this group, e.g. biotin. The possibility that the role of these vitamins in root metabolism could be investigated by using the appropriate 'anti-vitamins'[5] has not yet been explored.

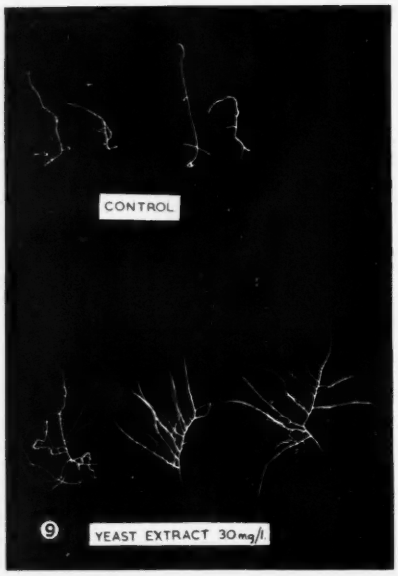
Deficiencies of the major nutrient elements (K, Ca, Mg, N, P, S, Fe) can be rapidly induced in excised root cultures. If one is studying micro-element deficiencies one needs to use special techniques to achieve the very high standard of purity which is essential in the preparation of the culture medium. It has now been possible, using excised tomato

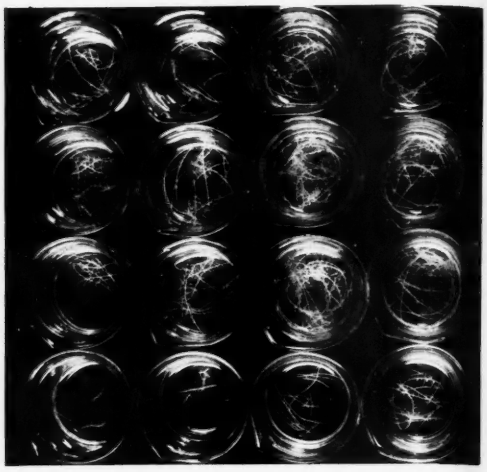
* Street, H. E., McGregor, S. M. and Sussex, I. M. *Journal of Experimental Botany* (in the press).

† Street, H. E. and Lowe, J. S. *Annals of Botany*, 1950, Vol. 14, p. 307.

‡ G. P. Harris, *Nature*, 1953, Vol. 172, p. 1003.

[5] Substances usually similar in chemical structure to the vitamins and specifically preventing their action, possibly by combining with those active centres of the cell normally occupied by the vitamin in question.





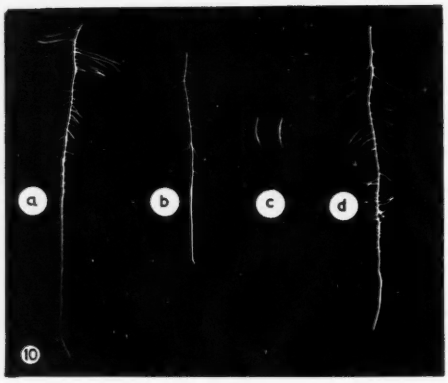




FIG. 9. Excised rye roots after 14 days' growth in medium with and without (control) 'Difco' yeast extract. FIG. 10. Glucose-galactose antagonism exposed by the growth of excised tomato roots. Carbohydrate present in the medium as follows: *a* 1% sucrose; *b* 1% sucrose + 0·25% glucose; *c* 1% sucrose + 0·05% galactose; *d* 1% sucrose + 0·05% galactose + 0·25% glucose. FIG. 11. Inter-relationship between molybdenum and manganese as shown by the growth of excised tomato roots. Both elements are essential for continued growth but a deficiency of either is alleviated by addition of the other at high concentration. (Each beaker contains an equal number of 7-day tip cultures.)

roots, to demonstrate absolute requirements for molybdenum and manganese,* and also the stimulatory effect of copper. The inter-relationships between molybdenum and manganese (Fig. 11), and their roles in nitrogen assimilation are now being investigated.

The nitrogen requirement of excised roots of tomato and of many other species is fully met by a supply of nitrate. Robbins and Bartley in 1938 reported the unexpected result that ammonium did not act as a satisfactory nitrogen supply. Recent unpublished work, however, shows that, under appropriate conditions, the ammonium ion is readily utilised and a careful study is now being undertaken of the factors controlling nitrate and ammonium assimilation. Work with groundsel roots† shows that certain amino-acids which stimulate growth in the presence of nitrate are capable, in its absence, of acting as the sole source of nitrogen. By virtue of the exclusion of micro-organisms from excised root cultures, it is possible to study the utilisation of organic nitrogen compounds as nitrogen sources for growth. When this is coupled with simultaneous nitrogen analysis of the roots, we can begin to trace the biochemical steps involved in nitrogen assimilation.

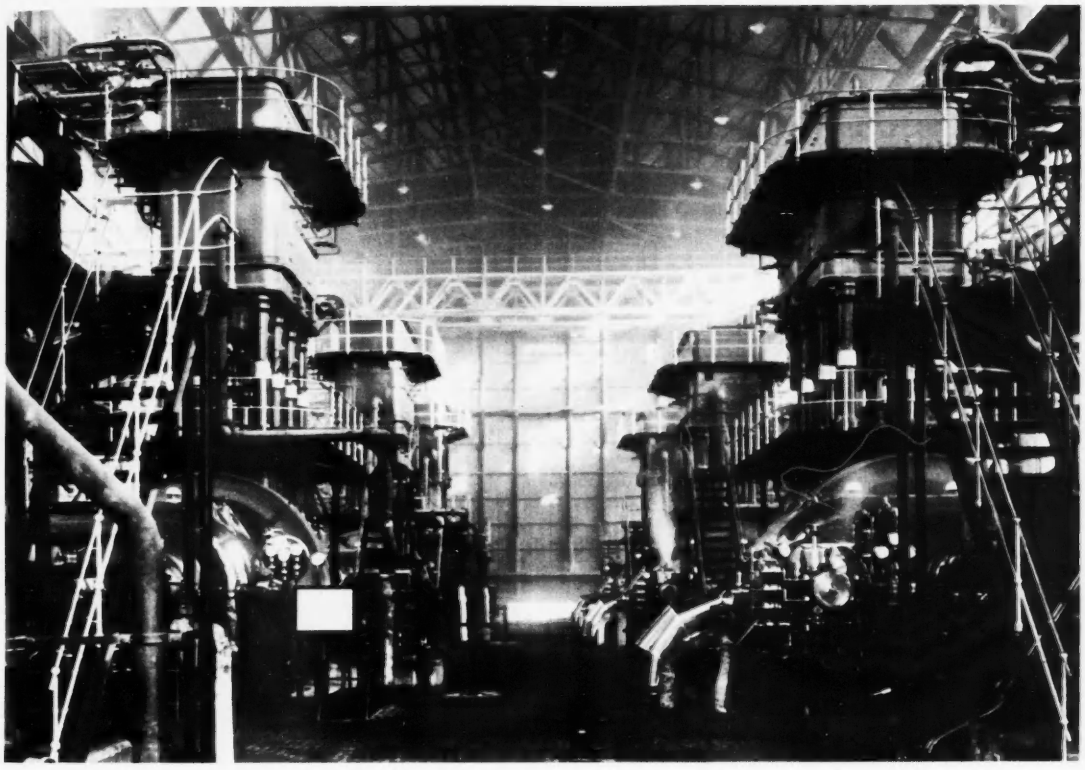
In this article I have attempted no more than to indicate the range of problems which can be investigated by the root culture technique; space does not allow a comprehensive survey to be made of this field of research. Most of the examples I have quoted refer to investigations initiated in the author's laboratory, and my sincere thanks are due to my research colleagues for permission to cite freely from their unpublished work.

* Hannay, J. W. and Street, H. E., *The New Phytologist*, 1954, Vol. 53, p. 68.

† Skinner, J. C. and Street, H. E., *The New Phytologist*, 1954, Vol. 53, p. 44.

## FURTHER READING

A key work in this field is P. R. White's *A Handbook of Plant Tissue Culture*, 1943. This book gives a detailed description of technique, and a review of the literature up to 1941.



Reciprocating gas compressors driven by high-speed steam turbines deliver gas at 250 atmospheres for ammonia synthesis.
*(I.C.I. photograph)*

# CATALYSIS IN INDUSTRY

Elsewhere in this issue the appearance of the first volume of a new compendium on catalysis is noticed. The review can only state that the present state of theory on the subject is outlined in this book, and indicate its interest to students of chemistry. A big gulf separates the theoretical considerations of catalysis and its practical applications. A great deal of the difficulty of bridging that gap is caused by the conditions in which most industrial catalysts work. They are not suitable for elementary laboratory demonstration, and a scientific subject which is taught only from books and not by experiment is under a handicap.

The essential purpose of a catalyst is to make a chemical reaction go at reasonable speeds. In a school laboratory we can take ethyl alcohol and acetic acid, add sulphuric acid, and boil the lot under a reflux condenser until an equilibrium between ethyl acetate, ethyl alcohol and acetic acid is reached. The course of the reaction can be studied by following the change in acid concentration. It is a good experiment because it demonstrates catalysis, and also the concepts of mass action and chemical equilibrium, besides typifying esterification in organic chemistry. But it does not demonstrate typical industrial manufacture of ethyl acetate, which is mostly made by the condensation of two molecules of acetaldehyde with aluminium ethoxide as a catalyst (Titschenko's reaction).

The kind of reaction which is the basis of many large-scale chemical manufactures is more often a reaction involving gases and a solid catalyst. Many of these are carried out at high temperature and under pressure. High temperatures are used to speed up the rates of reaction, the simple, rough rule being a doubling of the reaction rate for a rise in temperature of 10°C. The basis of this lies in the kinetic theory of gases, that increase in temperature gives an increase in the velocity of molecules and hence in the number of collisions between them. Chemical reaction can only occur between molecules which collide. Increase in pressure by diminishing the mean free path of molecules also increases the number of collisions.

High temperatures and pressures may have the disadvantage of moving the position of equilibrium of a chemical reaction so that although a reaction is speeded up. The reverse reaction is speeded up still more. This possibility can be predicted by Le Chatelier's principle, which applies to systems which are approximately in static equilibrium. It is that any physical or chemical change will be forced backwards by a change in the physical properties of the same type as that naturally produced by the reaction.

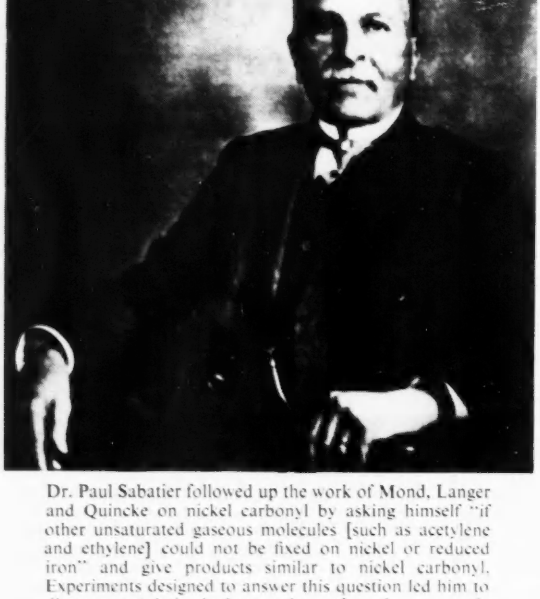
We can take as one example the reaction of sulphur dioxide and oxygen to give sulphur trioxide. This is the basis of the manufacture of sulphuric acid. In the 'contact'

process, sulphur or sulphides are burnt in air to give a mixture of sulphur dioxide, oxygen and nitrogen, which is passed over a 'contact' mass of vanadium pentoxide catalyst. The combination of the gases is exothermal, that is it evolves heat. By Le Chatelier's principle a low temperature will favour the production of sulphur trioxide. In practice it is found that almost complete conversion of the gases to sulphur trioxide takes place at 380° C. At temperatures above this, some remain unconverted. Industrial equipment is therefore designed so that the bulk of the reaction takes place in one catalyst bed from which the gases emerge at around 500° C. They are cooled down to around 350° C, and are then passed through a second bed of catalyst where the final conversion takes place and the gases leave at about 400° C through the rise in temperature caused by the mopping-up reaction.

## NITROGEN FIXATION BY THE SYNTHESIS OF AMMONIA

The effect of pressure can be seen in the production of synthetic ammonia. The basic reaction in this process is one in which three molecules of hydrogen react with one molecule of nitrogen to produce two molecules of ammonia. For molecules, one can substitute the word 'volumes' and proceed to consider how pressure affects the reaction. A reduction of volume is favoured, according to Le Chatelier's principle, by an increase in pressure.

A pressure typical of ammonia synthesis plants is 300 atmospheres, which is quite high. An iron catalyst is used, and the process was developed by Haber in 1914 in time to make Germany independent of imported Chile saltpetre, as the raw material needed for the manufacture of nitric acid needed to boost the production of explosives. The process was only possible because of Krupp's ability to make the thick forged catalyst chambers capable of standing huge pressures involved. After the 1914–18 war, the Bethlehem Steel Company in the United States set to and made similar forgings, but it was a long time after that British steel-works were able to cast a steel billet of sufficient size and forge it. A fuller account of this process (and others carried out at high pressures) was given by E. W. Sawyer of I.C.I. in DISCOVERY (May 1951). The use of noble metal catalysts in this connexion has been discussed in a "Progress of Science" note (DISCOVERY, August 1950).



Dr. Paul Sabatier followed up the work of Mond, Langer and Quincke on nickel carbonyl by asking himself "if other unsaturated gaseous molecules [such as acetylene and ethylene] could not be fixed on nickel or reduced iron" and give products similar to nickel carbonyl. Experiments designed to answer this question led him to discover catalytic hydrogenation of various organic compounds.

Clearly these temperatures and pressures are beyond the scope of normal laboratory experiments. Indeed, they remain outside the experience of many industrial chemists, and this is a pity, because these large-scale catalytic processes are great broadeners of the mind and give confidence in tackling processes which appear very difficult. Industry could help to make the approach to industrial catalysis easier by showing how small-scale experiments could be set up for teaching purposes. One of these might be hydrogenation, the fundamentals of which were investigated by Sabatier (1854–1941). Hydrogenation has been taken for granted in the manufacture of margarine for many years. The addition of hydrogen at double bonds in fats can be carried out at quite moderate temperatures and pressures, e.g. 70° C and 100 pounds per square inch pressure. The hydrogen can be obtained under pressure in cylinders and active nickel catalyst can be prepared quite easily. The simplest is probably Raney nickel made by dissolving the aluminium from an aluminium-nickel alloy with caustic soda solution. The course of the reaction can be followed by charging a hydrogen reservoir under moderate pressure, around 200 pounds per square inch, and following the rate of fall in pressure.

This kind of experiment would give a good introduction to catalysis, although it cannot demonstrate the problems that arise because of the scale of industrial work. These are mainly chemical engineering problems involving addition or removal of large quantities of heat. Many devices exist to overcome these. Addition of heat is sometimes possible by adding superheated steam to the reactants as in the dehydrogenation of ethylbenzene to styrene. The removal of heat from strongly exothermic reactions is usually facilitated by the fluidised-bed technique.

The use made of catalysis by industry is a fascinating study, which shows that most academic methods of chemical preparation are academic in the sense that they only demonstrate structural connexions. The industrial preparation most often starts by searching for a cheap raw material and then studying how a catalyst can mould it into the required shape. F.E.W.

### REFERENCES

An article describing in greater detail the high-pressure ammonia synthesis appeared in DISCOVERY, May 1951, p. 139 ("High-pressure Chemistry" by E. W. Sawyer of I.C.I.'s Billingham Division).

An article about Sabatier, by E. M. Friedwald, who was one of his students, was published in DISCOVERY, July 1949, p. 209 ("Pioneer of Hydrogenation"). See also Sabatier's own account "How I have been led to the direct hydrogenation method by metallic catalysts", published in *Ind. & Eng. Chem.*, October 1926, pp. 1005–8.

# HAEMOPHILIA: NEW LIGHT ON AN OLD PROBLEM

A. C. ALLISON
D.Phil., B.M.

The picture of a child or young man losing his life's blood from a small wound must have left a lasting impression on the ancients. In the *Tractat Jebamoth* of the Talmud a prolonged bleeding tendency is listed as a dispensation from the firm covenant given by God to Abraham: "Every man child must needs be circumcised; and my covenant shall be in your flesh for an everlasting covenant."*

A number of incidental references to a bleeding tendency among males occur in the writings of the Arabs and 17th-century European physicians, but the first accurate account of haemophilia seems to be that published by the German physician Consbruch in 1793: "On the fourth of November I was called into the country to see an eleven-year-old boy who two days before had cut his thumb, and, without being able to stop the flow of blood by any means, bled to death before I could reach the spot. A brother of this boy several years before had likewise bled to death from a slight wound. Several brothers of the mother had died in the same way. All of the female sex in the family are, so far as I know, free from this unfortunate idiosyncrasy."

We have in this account the distinctive feature of the disease later termed by the German pathologist Schönlein *haemophilia* ('bleeding tendency'). This predisposition to prolonged bleeding which appears in some males of a family is transmitted by certain females who are themselves quite unaffected.

The inheritance of the disease is illustrated by the family of Queen Victoria, who was a carrier of haemophilia. Of her four sons, three were healthy, whereas one (Prince Leopold) was a haemophilic who lived to marry and produce a daughter and posthumous son. The occurrence of the disease among her daughters' descendants has become a matter of history. The present English royal family is not liable to haemophilia, since King Edward VII, being normal in this respect himself, could not have transmitted the gene.

When the genetics of sex determination was discovered, an explanation for the curious mode of inheritance of haemophilia could be advanced: that haemophilia is probably transmitted as a sex-linked recessive character located on the non-pairing part of the X-chromosome. This interpretation has been established only quite recently.

The mode of inheritance of haemophilia is illustrated in Chart I. This chart is well known, but its consequences are often misunderstood. The male haemophilic does not transmit the defect to his sons, but his daughters are all potential carriers of the gene. The children of a female transmitter have an equal chance of being normal, or of being transmitters if girls, or haemophilics if boys.

Normal blood will clot in a few minutes. In strong contrast to this, haemophilic blood will not clot for an hour or more. That haemophilia due essentially to a defect in the clotting mechanism of the blood was pointed out by Sir Almroth Wright in 1893: the blood-vessels and platelets are not abnormal, as they may be in other hereditary bleeding diseases. For half a century it has been known that the addition of a small quantity of normal blood to haemophilic blood will reduce the clotting-time of the latter to normal. Much more recently it has been shown that the substance which shortens the clotting-time of haemophilic blood is a protein present in normal blood plasma but absent in haemophilic plasma. For want of a better term, this substance has been called *antihaemophilic globulin*, which is more closely allied to fibrinogen than globulin. Thus a single complex of proteins is intimately concerned in the initial as well as the final stages of blood-clotting. In some way which is still imperfectly understood, antihaemophilic globulin and certain other factors are necessary for the formation of active thromboplastin, which in turn carries on the sequence of events leading to coagulation (Chart 2). The genes controlling the formation of antihaemophilic globulin are located in the X-chromosome. The presence of one such gene is necessary to produce enough antihaemophilic globulin for normal blood-clotting, but in haemophilia this gene is either defective or absent, so that very little or no antihaemophilic globulin is formed.

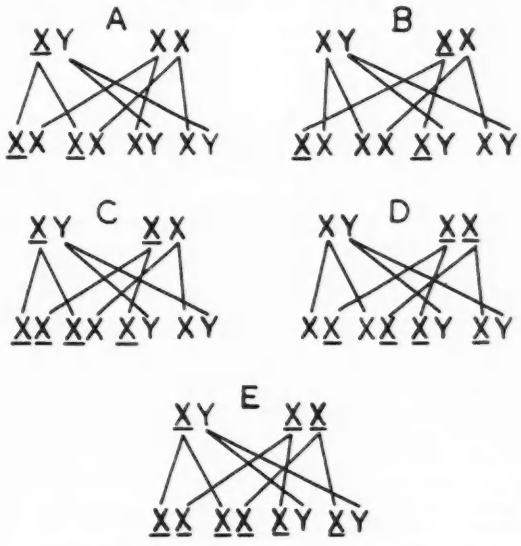



CHART I. The inheritance of haemophilia. The X-chromosome on which the haemophilia gene is located is marked. *X*. Female carriers of the disease are of constitution *XX*, female haemophilics *XX* and male haemophilics *XY*.

* Genesis xvii, 10

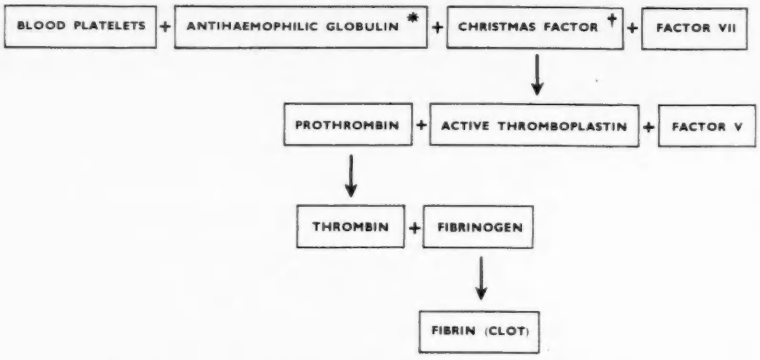



CHART 2. The important reactions concerned in blood clotting. Calcium ions are required for the formation of active thromboplastin and thrombin. In haemophilia, antihaemophilic globulin* is deficient; in Christmas disease, the Christmas factor† is deficient. In both these diseases the formation of active thromboplastin is slow so that the clotting time of the blood is increased.

The blood-clotting mechanism appears more and more complex yearly as new factors participating in it are isolated. Factor V and Factor VII are present in normal amounts in haemophilic blood, so they are not implicated in the disease and need not concern us here. However, in the *British Medical Journal* (December 27, 1952) the discovery of yet another factor necessary for the formation of active thromboplastin was reported by Biggs and her colleagues. This was termed 'Christmas Factor': it owed its name not to the season when the discovery was published but to the surname of the first patient involved. (This is, incidentally, one of the few instances when a disease has been named after a patient.) The 'Christmas' disease is closely allied to haemophilia in both its manifestations and its inheritance, so that the two conditions have always been confused. Patients with this disease have a normal quantity of anti-haemophilic globulin, however, so that the addition of their blood to haemophilic blood will greatly accelerate the clotting of the latter, and vice versa. Christmas factor and antihaemophilic globulin are quite distinct from each other in their physico-chemical reactions: Christmas factor is precipitated with the $\alpha$- and $\beta$-globulins, it is heat-labile and easily adsorbed on aluminium hydroxide, whereas antihaemophilic globulin is precipitated with fibrinogen, resistant to heat, and not adsorbed with aluminium hydroxide. The separation of haemophilia into two quite distinct diseases raises a number of genetical problems which at present can only be answered tentatively. It is of considerable theoretical interest that the genes responsible for the production of two factors necessary for the initial stages of blood coagulation should be linked in the non-pairing part of the X-chromosome.

The relative frequency of the two diseases in different countries seems to vary considerably. In Switzerland the two diseases are about equally common, in Holland the ratio of patients with Christmas disease to haemophilics is about one to three, and in England about one to ten; in Canada several cases of Christmas disease are on record, whereas in the United States of America it is a great rarity. There is as yet no explanation for this distribution: the evidence suggests that the mutation rates from the normal to the two disease conditions differ in different populations; that is, in different genetic environments.

We shall now have to re-examine all the accepted pedigrees of haemophilia to ascertain which of the families have Christmas disease. The limited data at present available suggests that Christmas disease is rather more variable than haemophilia in its manifestations, and that haemophilia tends to arise the more frequently *de novo* by spontaneous mutation. Haemophilics number about 1 in 50,000 of the population of Britain; some 25–30% of all cases of haemophilia are new mutants. In this connexion, haemophilia has been described by Quick and Conway (*Amer. J. Med.* Vol. 7, 1949, p. 841) in one of a pair of identical twins, which is strong suggestive evidence of mutation. In 1949 Haldane estimated that the mutation rate from the normal to the haemophilic condition is about $3{\cdot}2\times10^{-5}$ (i.e. one mutation for every 31,250 genes each generation). This estimate is probably rather too high and $10^{-6}$ seems to be a reasonable approximation of the true figure. The mutation rate in the case of the gene controlling the appearance of Christmas disease appears to be of the order of $10^{-7}$.

Two lines of investigation are now being actively pursued. The most important thing is, of course, to find an effective treatment for haemophilic patients. The second concerns the recognition of female carriers. If female carriers could be recognised with reasonable certainty, many of them would choose to remain childless, and a very considerable reduction in the incidence of haemophilia could be achieved within two or three generations. As it is, many affected women gamble on the 50% chance that they are free from the condition and produce families, thereby propagating the disease. Female carriers sometimes have slightly abnormal bleeding tendencies, which were thought at one time to be sufficiently marked to allow their identification. It is possible that more sensitive techniques would detect minor disturbances in the clotting mechanism, thereby demonstrating the presence of the haemophilic gene in the heterozygous condition. Another possibility is the discovery of some common gene located on the X-chromosome, like the sex-linked blood-groups of birds, which would permit the identification of the affected chromosome as it appears among the offspring of a female carrier. A common sex-linked character has recently been described in man; those who are affected cannot smell cyanide solutions. Because the character is recessive, however, it cannot be recognised in the heterozygous phase, and it is therefore of limited value in the detection of female carriers of haemophilia. Any technique allowing recognition of haemophilic heterozygotes would alleviate a great deal of anxiety on the part

of women who might be carriers, and they would reduce the seriousness of the haemophilia problem in later generations.

The only effective treatment of haemophilia at present available is the transfusion of fresh blood in large quantities. This measure replaces the blood which has been lost, and at the same time it provides sufficient antihaemophilic globulin to shorten the clotting-time of the patient and thereby prevent further haemorrhage in an emergency. Since methods are available for concentrating antihaemophilic globulin, a great deal of time and energy has been given to the development of techniques which would provide enough antihaemophilic globulin for substitution therapy—i.e. periodic treatment of haemophilics in the same way that diabetics are treated with insulin. Unfortunately the amount of antihaemophilic globulin in normal blood is very small, so that vast quantities of blood plasma would be required. It can be estimated that to give continuous treatment to all the haemophilics in Great Britain, at least one-third of the blood collected by the National Blood Transfusion Service would have to be used for this purpose alone; this is not, of course, a feasible proposition, and therefore attention has been focused upon the possibility of preparing antihaemophilic globulin from animal blood.

Progress in this field has always been slow because of the difficulty of assaying the antihaemophilic potency of different preparations. Most investigators have relied upon shortening of the clotting-time of haemophilic blood as a test. For this purpose it is necessary to have haemophilics at hand, and one is reluctant to bleed such patients often. Haemophilia in dogs is, unfortunately, very rare, but in those laboratories where haemophilic dogs have been available their blood has been used in such investigations. Recently a simple test which obviates this difficulty, has been developed. This is called the 'thromboplastin generation test', and it allows separate assay of the activity of each one of the components required for the formation of active thromboplastin. Now that this test is generally available, we may be sure that progress will be greatly accelerated. Reports have already appeared describing new techniques for concentrating antihaemophilic globulin from ox serum. These preparations have not yet been tried in human patients. The use of foreign proteins in the treatment of human disease is not without its difficulties, mainly because compounds of such high molecular weight are often antigenic, stimulating the production in the patient of antibodies. But this has not proved an insuperable obstacle in the case of insulin and the adrenocorticotrophic hormone. The next few years should turn out to be the most exciting of all in the long history of research on haemophilia.

## WHERE DO CAMELS STORE THEIR WATER?

How the camel can endure extreme desert conditions is still a mystery. When fresh vegetation is available, the camel gets adequate water from it and does not need drinking water. A thirsty camel, however, can drink more than ten gallons (40 litres) in a few minutes without ill effects. But where he puts it is not known; the so-called 'water compartments' of its stomach do not indicate that the water is stored there. The excretion of water by the camel is extremely low and there is practically no excretion of urea when the diet is low in protein.

These facts emerge from the study of the physiology and ecology of the camel which is one of the projects of Unesco's Advisory Committee on Arid Zone Research. At Beni Abbès, in Algeria, a group of research workers under the direction of Dr. Knut Schmidt-Neilsen, Zoology Professor at Duke University, has set up a complete modern laboratory for studies of metabolism and heat exchange, and for the analysis of body fluids.

During the past winter, basic information on the heat transfer through the fur of the camel, the structure of the camel kidney, its body temperature and its respiration was also obtained and will be compared with measurements to be made this summer in order to determine the physiological factors that are responsible for the extraordinary tolerance of the camel for dehydration.

Another Unesco project is the role of vertebrate animals in preserving and spreading desert conditions, especially by feeding on desert vegetation. Chief responsibility for destruction of vegetation in the Rajasthan desert in India belongs to goats, sheep, cattle, camels and rodents. Snakes and lizards do little or no damage to vegetation and may even be helpful. The research, under the direction of Dr. D. Krishna, of Jaswant College, includes the study of the role of birds and the exact feeding habits of all the desert animals. The work is being done under a grant from Unesco and in co-operation with the authorities of Rajasthan State and the Government of India.

The latest meeting of Unesco's Advisory Committee on Arid Zone Research, held in Paris in May, also heard from the international Sahara and Sudan expedition headed by Dr. F. Kollmannsperger, of Saarbrücken. This expedition has crossed the Sahara from Laghouat to Agades and travelled over the Hoggar mountains by camel. It has visited Lake Chad, and the expedition's biologists are now working in the Enedi mountains. The expedition is studying agricultural and irrigation practices in the arid area and the soils. So far it has collected nearly 1200 specimens of birds and mammals.

# FAR AND NEAR

**The Oppenheimer Affair**

It was Bertrand Russell who once suggested that, but for his indispensability, the scientist would be persecuted all over the world. In some countries the reaction to this suggestion was a shrug of the shoulders, and the hope that it would not happen in any civilised country led to the familiar 'It-can't-happen-here' attitude. Too much the scientific world has relied upon the apparent indispensability of its members, which is a poor basis on which to build security, for it implies that indispensability entitles a particular class of specialists to special privileges within a community.

The Oppenheimer affair has opened many eyes. Unfortunately, the full facts of the case have not been reported in the majority of British newspapers, whose reports in this instance have tended to have a distinctly anti-American bias, though this may have been the bias of ignorance rather than the bias of real prejudice. A long time ago it became known that a serious clash of opinion had arisen within the U.S. Atomic Energy Commission: on the one side were David Lilienthal (then A.E.C. chairman) and Dr. Robert Oppenheimer, and on the other Lewis Strauss. Somewhere in the picture was Dr. Teller, the scientist who pinned as much faith on the possibility that hydrogen bombs could be made as Dr. Oppenheimer had had in atomic bombs in the early days of the Los Alamos laboratory where bombs were eventually constructed in 1945. (Dr. Oppenheimer was the director of the Los Alamos laboratory.)

Lilienthal resigned his chairmanship of the A.E.C. over President Truman's decision of 1950 to authorise the H-bomb project, and he was prompted to do so for reasons which are still somewhat vague: he said at the time that he had "a visceral feeling that this is wrong". Dr. Oppenheimer, a key man in A.E.C. circles and the first chairman of its nine-member General Advisory Committee which advises on scientific and technical matters, remained associated with A.E.C. after Lilienthal's resignation, in spite of the fact that it was to Dr. Teller that the new A.E.C. chairman turned for technical advice on the H-bomb.

The H-bomb project was given the priority of a 'crash' production programme on the President's instructions, and in Nov. 1952 the first H-bomb was exploded; this test which was code-named 'Operation Ivy', led to the vaporisation of Elugelab Island in the Eniwetok Atoll. Soon afterwards—in Aug. 1953—Russia exploded her first H-bomb.

In April 1954 the news broke that since the end of 1953 Dr. Oppenheimer's security clearance was suspected, on the direct personal order of the U.S. President, and he was denied further access to secret information. A special security board—composed of one university president, one emeritus university professor of chemistry, and the retired president of the Sperry Corporation—spent eight weeks investigating the case.

The board's findings were published in June. They absolved him of any charges of present-day disloyalty or of any "attachment to the Soviet Union"; they commended him for his "high degree of discretion, reflecting an unusual ability to keep to himself vital secrets".

When it came to deciding whether Dr. Oppenheimer should have restored to him his access to secret information, the board could not agree. The chemistry professor considered that Dr. Oppenheimer should be given full security clearance and be trusted with classified information. The two other members of the board took the opposite view.

The majority's view was based on the following considerations:

(1) "We find that Dr. Oppenheimer's continuing conduct and associations have reflected a serious disregard for the requirements of the security system.

(2) "We have found a susceptibility to influence which could have serious implications for the security interests of the country.

(3) "We find his conduct in the hydrogen bomb programme sufficiently disturbing as to raise a doubt as to whether his future participation, if characterised by the same attitudes, in a Government programme relating to the national defence would be clearly consistent with the best interests of security.

(4) "We have regretfully concluded that Dr. Oppenheimer has been less than candid in his testimony before this board. . . .

"There can be no tampering with the national security, which in times of peril must be absolute, and without concessions for reasons of admiration, gratitude, reward, sympathy or charity. Any doubts whatsoever must be resolved in favour of the national security. The material and evidence presented to this board leave reasonable doubts with respect to the individual concerned. We, therefore, do not recommend reinstatement of clearance."

The board went into Dr. Oppenheimer's record with regard to the H-bomb project with very great care. Their conclusion was that his conduct on the H-bomb was "sufficiently disturbing to raise a doubt". As late as autumn 1949 Dr. Oppenheimer took the line that he was willing to grant an all-out H-bomb programme "a better than even chance" of success within five years, though "he was aware that the efforts being put forth were relatively meagre and if research were continued at the same pace, there would be little likelihood of success for many years". In that same year, after Lewis Strauss had proposed that an all-out H-bomb programme should be started, "Dr. Oppenheimer strongly opposed the development of the hydrogen bomb on moral grounds, on grounds that it was not politically desirable," as well as because the H-bomb programme would be a drain on the orderly development of the fission bomb programme. The report added: "Until the late spring of 1951, he questioned the feasibility of the hydrogen bomb efforts then in progress." (In actual fact, the U.S. H-bomb programme proved to be no drain on the fission bomb programme, though that could not have been accurately and firmly predicted by any scientist in 1949.)

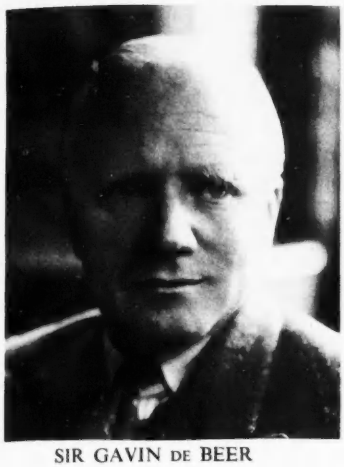
Dr. Oppenheimer told the board that he had opposed only a 'crash programme' of H-bomb production in 1949. The board, however, did not believe this testimony to be "entirely candid", having discovered a minute which Dr. Oppenheimer had written in 1949 containing this sentence: "The super-bomb should never be produced." That opinion "became widely known among scientists, and since he did not make it known that he had abandoned these views, his attitudes undoubtedly had an adverse effect on recruitment of scientists. . . . In other words, the board finds that if Dr. Oppenheimer had enthusiastically supported the thermonuclear programme . . . the H-bomb project would have been pursued with considerably more vigour."

The board's report continues: "The opposition to the H-bomb by many persons connected with the atomic energy programme, of whom Dr. Oppenheimer was the most experienced, most powerful and most effective member, did delay the initiation of concerted effort which led to the development of a thermonuclear weapon. . . . We cannot dismiss the matter . . . simply with the finding that [Oppenheimer's] conduct was not motivated by disloyalty, because it is our conclusion that, whatever the motivation, the security interests of the U.S. were affected."

Dr. Oppenheimer is known to have disagreed with the Government's policy with regard to strategic air power, believing —as many others quite sincerely believe— that the emphasis should be put upon defence rather than attack. He is also known to have used his influence in an attempt to stimulate new lines of thought on the relative importance of air defence and attack. It is presumed that the board is referring to this aspect of Dr. Oppenheimer's many-sided activities when it remarks:

"We are concerned . . . that he may have departed his role as scientific adviser to exercise highly persuasive influence in matters in which his convictions were not necessarily a reflection of technical judgment, and also not necessarily related to the protection of the strongest offensive military interests of the country. In the course of the proceedings, there developed other facts which raised questions of such serious import as to give us concern about whether the retention of Dr. Oppenheimer's services would be clearly consistent with the security interests of the U.S."

These views represent the judgment of the board's majority. The minority



SIR GAVIN DE BEER

*In the list of Knights Bachelor in the Queen's Birthday Honours were two well-known scientists—Dr. Gavin Rylands de Beer, F.R.S., and Prof. F. E. Simon, F.R.S.*

*Dr. de Beer, who is director of the Natural History Museum in London is an expert on the embryology of vertebrates. His numerous writings including the widely used textbook "Vertebrate Zoology."*

*Prof. F. E. Simon of the Clarendon Laboratory, Oxford, needs no introduction to our readers. A refugee from Hitler's Germany, he played a key part in atomic bomb development, and did much work on the U235 gaseous diffusion process.*

SIR FRANCIS SIMON

report of Prof. Ward V. Evans, emeritus professor of chemistry at Loyola University of Chicago, was much more favourable to Dr. Oppenheimer. These are the main conclusions to which Prof. Evans came:

"[Dr. Oppenheimer] did not hinder the development of the H-bomb, and there is absolutely nothing in the testimony to show that he did," he wrote. "His statements in cross-examination show him to be still naïve but extremely honest, and such statements work to his benefit in my estimation. . . . No one on the board doubts his loyalty . . . and he is certainly less of a security risk than he was in 1947 when he was cleared [by a Truman loyalty board]. . . . His judgment was bad in some cases, and most excellent in others, but, in my estimation, it is better now than it was in 1947, and to damn him now and ruin his career and his service, I cannot do it . . . I personally think that our failure to clear Dr. Oppenheimer will be a black mark on the escutcheon of our country . . . I am worried about the effect an improper decision may have on the scientific development in our country."

The board included in its report an important statement of "General Considerations" involved in matters of security and loyalty. This included a reference to the 'alarm reaction' of the scientific community whereby scientists might take an adverse view of any board decision that was unfavourable to Dr. Oppenheimer—a serious matter since recruitment of indispensable scientists for Government might be affected to the nation's detriment. This is the board's comment on this fundamental issue:

*We should express our considered view that, because the loyalty or security risk status of a scientist or any other intellectual may be brought into question, scientists and intellectuals are ill-advised to assert that a reasonable and sane inquiry constitutes an attack upon scientists and intellectuals generally. This board would deplore deeply any notion that scientists are under attack in this country and that prudent study of any individual's conduct and character within the necessary demands of the national security could be either in fact or in appearance a reflection of anti-intellectualism.*

*The board has taken note of the fact that in some cases of this sort groups of scientists have tended towards an almost professional opposition to any inquiry about a member of the group. They thus, by moving in a body to the defence of one of their number, give currency, credence and support to a notion that they as a group are under attack.*

*We know that scientists, with their unusual talents, are loyal citizens, and, for every pertinent purpose, normal human beings. We must believe that they, the young and the old and all between, will understand that a responsible Government must make responsible decisions. If scientists should believe that such a decision in Government, however distasteful with respect to an individual, must be applicable to his whole profession, they misapprehend their own duties and obligations as citizens.*

*In this connection, the board has been impressed, and in many ways heartened, by the manner in which many scientists have sprung to the defence of one whom many felt was under unfair attack. This is important and encouraging when one is concerned with the vitality of our society. However, the board feels constrained to express its concern that in this solidarity there have been attitudes so uncompromising in support of science in general, and Dr. Oppenheimer in particular, that some witnesses have, in our judgment, allowed their convictions to supersede what might reasonably have been their recollections.*

* * *

Half of the May issue of *Bulletin of the Atomic Scientists* of Chicago (available in Britain from Cambridge University Press) is devoted to the Oppenheimer case, and contains protests from a number of prominent people, including Albert Einstein, S. K. Allison, Edward Condon, Harold C. Urey, Linus Pauling, S. A. Goudsmit, and Edward Shils. It was published prior to the publication of the report of the presidential security board, and no doubt the board's findings will now be analysed by the *Bulletin*.

**Night Sky in July**

*The Moon.*—Full moon occurs on July 16d 00h 29m, U.T., and new moon on July 29d 22h 20m. The following conjunctions with the moon take place:

| | | | | |
|---|---|---|---|---|
| 3d 15h | Venus in conjunction with the moon | | Venus | 5° N. |
| 9d 18h | Saturn | ,, | Saturn | 8° N. |
| 14d 00h | Mars | ,, | Mars | 3° S. |
| 28d 08h | Jupiter | ,, | Jupiter | 0° S. |
| 28d 08h | Mercury | ,, | Mercury | 2° S. |

In addition to these conjunctions with the moon, Venus is in conjunction with Regulus on July 12d 08h, Venus 1° 1′ N., and Mercury is in conjunction with Jupiter on July 28d 00h, Mercury 1° 9′ S.

*The Planets.*— Mercury is in inferior conjunction on July 6, but after the middle of the month it can be seen as a morning star, its time of rising on July 31 being 2h 50m, that is, about 1½ hours before sunrise. Its conjunction with Jupiter on July 28 has already been pointed out. Venus sets at 22h 20m, 21h 50m and 21h 15m on July 1, 15 and 31 respectively; its stellar magnitude varies between −3·5 and −3·6 and the visible portion of its illuminated disk between 0·76 and 0·66. Mars is visible throughout the night, setting in the early morning hours at 2h 40m, 1h 20m and 0h 15m on July 1, 15 and 31 respectively. On July 14 it will make a close approach to the moon, conjunction occurring at 0h, but of course it will remain fairly close to the moon for some time before and after this hour; as the moon is nearly full at this time it will make the observation of Mars somewhat difficult. Jupiter is too close to the sun at the beginning of the month for observation, but on July 15 it rises at 3h—an hour before sunrise—and at the end of the month at

2h 25m. The conjunction of Mercury and Jupiter with the Moon on July 28 has been pointed out. Saturn rises early in the afternoon and sets at 0h 40m, 23h 30m and 22h 40m on July 1, 15 and 31 respectively. It is stationary on July 7, after which its apparent motion will be westward, its movement taking it slowly away from κ Virginis.

A partial eclipse of the moon takes place on July 15–16, and is visible at Greenwich. The circumstances of the eclipse are as follows:

| | |
|---|---|
| Moon enters penumbra | 15d 21h 47·7m |
| Moon enters umbra | 15d 23h 09·4m |
| Middle of the eclipse | 16d 00h 20·3m |
| Moon leaves umbra | 16d 01h 31·3m |
| Moon leaves penumbra | 16d 02h 52·9m |

The magnitude of the eclipse is 0·411, the moon's diameter being 1.

### Centenary of George Eastman

To commemorate the hundredth anniversary of the birth of George Eastman, a U.S. postage stamp will be issued bearing his portrait.

George Eastman, who has been called the father of modern photography, was born in the village of Waterville, New York, on July 12, 1854. He first became interested in photography at the age of twenty-three. After mastering the clumsy wet-plate process then in general use, he turned his attention to the newly invented gelatine dry plate. In 1879 he received a patent for a plate-coating machine, and in the following year began to manufacture dry plates for sale. At that time there were only a handful of manufacturers of this product.

Within a very few years Eastman substituted for glass his perfected system of roll film photography, and in 1888 brought out a greatly simplified camera which he called the 'Kodak'. Anybody could take pictures with Eastman's box camera. No skill was required beyond the ability to press a button. The finishing of the pictures was done in the factory. Photography was brought to all.

One of Eastman's most famous deals was the one whereby he acquired the monopoly of 'Velox' printing paper. This printing paper was one of the earliest inventions of Leo Henrik Baekeland (the inventor of 'Bakelite'). Baekeland had produced this paper, which made it possible to obtain prints by artificial light, because he had decided that such an invention was "the one single thing which offered the best chance for the quickest possible results"—he was then figuring out a way of meeting his accumulation of debts. Professional photographers proved to be uninterested in 'Velox' printing paper, so Baekeland and his partner Leonard Jacobi marketed the new photographic paper through their own firm (the Nepera Chemical Co.) and sold it to enthusiastic amateur photographers who proved more enterprising than the professionals. The fame of 'Velox' grew, and one day Baekeland received a letter from Eastman who wrote that he was interested in buying the invention. The inventor thought it might be worth 50,000 dollars, but had made up his mind that he would accept 25,000 dollars. He was therefore more than surprised when they met and Eastman said, "Will you take a million dollars for 'Velox'?" They clinched the deal on the spot, and Baekeland thus became rich enough to be able to indulge his taste for research and leisurely invention, which finally yielded the remarkable substance now known throughout the world as 'Bakelite'.

In 1889 Eastman put on the market flexible transparent film. When Thomas A. Edison was designing the kinetoscope he faced an insuperable problem in finding proper material until Eastman's new transparent film came to his attention. Successful moving pictures became possible when Edison used Eastman's flexible film in his camera in the late 1880's.

George Eastman created a great photographic industry. Under his constant and personal direction immeasurable advances were made in the technique of photography.

The world-wide Kodak organisation which George Eastman founded has factories and experimental centres today in England, the United States, Australia, Canada, France and Germany, and manufactures photographic products for industry, medicine, education and science, as well as for the hobby and craft of amateur photography and for the motion-picture industry.

George Eastman was known as a philanthropist almost as well as he was known as the creator of a new era of photography. He gave dental clinics to London, Paris, Rome, Brussels and Stockholm, and large sums of money to educational institutions. In all he gave away over one hundred million dollars.

An exhibition commemorating the centenary of George Eastman will be held at the Royal Photographic Society, 16 Princes Gate, London S.W.7, during the month of August.

### Royal Society Rutherford Memorial Appointments

Under the terms of the scheme to commemorate the late Lord Rutherford of Nelson the following appointments are announced by the Royal Society:

DR. E. MARSDEN, of New Zealand, has been appointed as the Rutherford Memorial Lecturer for 1954. Dr. Marsden is delivering a series of lectures at university centres in South Africa.

MR. D. M. BRINK, a graduate of the University of Tasmania, has been appointed a Rutherford Scholar for three years from October 1, 1954, to carry out research in nuclear physics at the Clarendon Laboratory, Oxford.

### Scholarship Grants for Plastics Education

Further developments in various educational fields are reported by the plastics industry following a recent meeting of the trustees of the Plastics Industry Education Fund. In addition to allotting £1000 for the third year in succession for training grants to students working full-time for a science degree, £1000 a year for the next two years has been allotted for bursaries for students taking the two-year diploma course at the Borough Polytechnic in London.

To increase facilities for training in plastics technology in the Midlands, £1000 a year for the next two years has been allocated for scholarships to students taking the full-time Associateship course at the Birmingham College of Technology.

## *LETTERS TO THE EDITOR*

## LYSENKO AND THE BIGGEST BEETLE

Sir:

Once again your backwood-boys have blundered (DISCOVERY, May 1954, "Lysenko under Fire"). Lysenko has *not* been repudiated, he *is as influential and brilliantly successful as ever*. Each time some Yankee rag prints a forgery you fall for it! This is the fourth time to my knowledge this idiocy has occurred in the British press. Langdon-Davies! Imagine instancing *that* rubbish!!! In an allegedly scientific paper you appear to be remarkably prejudiced and gullible. *You can print one less copy in future.*

Yours, etc.

H. RUSSELL WAKEFIELD.

*13 Coleherne Road,*
*London, S.W.10.*

Sir:

I have enjoyed reading Mr. Snow's most interesting article on Fiji and Tonga (DISCOVERY, February 1954) as it is both well written and illustrated.

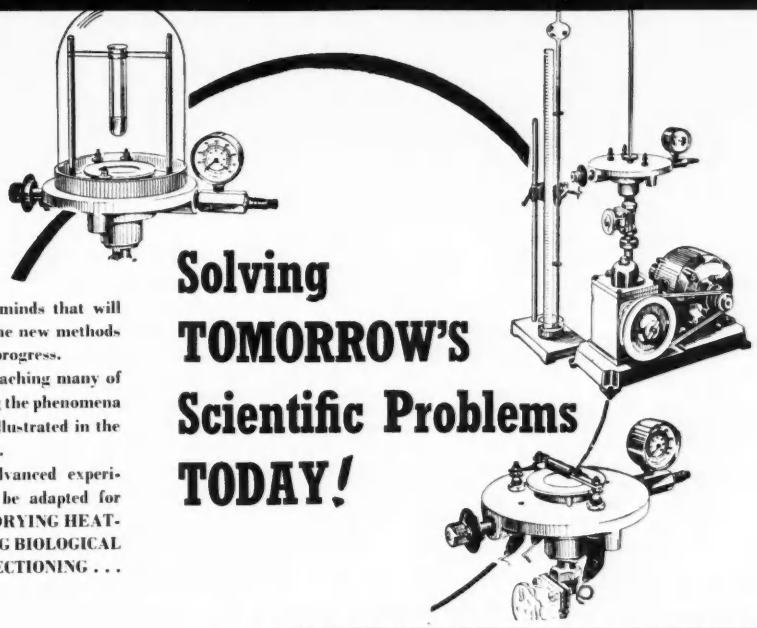
May I query one or two of his remarks on the natural history of these islands where I recently lived for nine years? The total spread of one and a half feet attributed to the beetle is not really possible; the world record for body length in beetles is about six inches.

On page 69 it is said that the jungle plant *Tangimauthia* is restricted to Taveuni Island; it was, however, found in the mountains of Vanua Levu in 1934 by the American botanist A. C. Smith.

Yours, etc.

R. A. LEVER.

*5 Lake View Chalet,*
*Lake Gardens,*
*Kuala Lumpur,*
*Malaya.*



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# THE BOOKSHELF

### Catalysis

Edited by Paul H. Emmett. Vol. 1. (*New York, Reinhold Publishing Corporation: London, Chapman & Hall, 1954, 394 pp., 80s.*)

This is the first of two volumes dealing with the fundamental theory of catalysis, to be followed in due course by further volumes which will deal comprehensively with the practice of catalytic processes.

The book begins by setting out the present state of speculation on the way in which gases are adsorbed physically or chemically on to solid surfaces or into capillary pores. This leads to the measurement of catalyst surface areas by low-temperature gas adsorption techniques or the pressure-drop methods of Kozeny and Carman.

Practical methods of catalyst preparation in industrial use are discussed, and the influence of promoters and poisons. The lead of practice over theoretical interpretation is clearly brought out. In small ways, even this volume is not quite in step with the advances in practical catalysis made possible by the fluidised bed technique, such as the modern 'cat-cracker'. But it is a welcome systematisation of available knowledge and the later volumes will no doubt pick up the details. An interesting chapter deals with the relation between magnetic and catalytic properties, while the phenomenon of semi-conductivity and lattice-defective structures is dealt with in an earlier chapter (but is not indexed). The whole work should in time become the stand-by of all who have to work from the existing state of the art. F. E. W.

### Humphry Davy

By Prof. James Kendall (*London, Faber & Faber, 1954, 165 pp., 12s. 6d.*)

Humphry Davy was not only the foremost chemist of his time, he was also a fine poet, a clever essayist, a distinguished member of the medical profession, an excellent angler and a wide traveller. To write a biography of such a man, an author would have to be as varied in his interests. But Prof. Kendall's account is so fascinating that the reader may well believe that he has all the necessary qualifications (my only private doubt is whether his success with the rod is as great as his prowess with the pen!) In this concise biography he traces Davy's life from his humble beginning as an apothecary's apprentice until his death in Italy at the age of fifty on one of his travels to the Continent. It is an account which is so fascinating that I simply could not lay down this book until I had finished it. My interest was held throughout because it is written with great charm and wit, and with an obvious feeling of enjoyment that is infectious.

The book's sub-title, "Pilot of Penzance", gives a clue to the delight which is in store for the reader, although the author warns Gilbert and Sullivan devotees that many of the hidden quotations from *The Pirates of Penzance* scattered throughout the book will exercise their ingenuity in discovering them. One thing stands out. Davy was no ivory-tower scientist; the public flocked to his lectures at the Royal Institution, while his scientific investigations were often made with the predetermined aim of ameliorating the sufferings of man or the extension of knowledge for his material benefit. But there was one chance missed. While he was superintendent of the Pneumatic Institution at Bristol he carried out various investigations (some of them highly dangerous) on the physiological effects of various gases on the human system. In a publication dated 1800 he stated, "As nitrous oxide in its extensive operation appears capable of destroying pain it may probably be used with advantage during surgical operations, where no great effusion of blood takes place." What an opportunity was lost of putting this discovery into practice for the relief of human suffering. It was forty-four years later that Horace Wells, an American dentist, first employed this gas for the painless extraction of one of his own teeth.

At the age of 22, Humphry Davy joined the Royal Institution as director of the laboratory; at 23 he became Professor of Chemistry there; at 24 he was elected a Fellow of the Royal Society, and at 29 he was appointed its secretary. It is an amazing success story of a young man from the country that should inspire the younger generation for whom this book is primarily intended.

Prof. Kendall's account of Davy's associations with the eminent scientists of the day—Dalton, Galvani, Volta, Ampère, Gay-Lussac—especially during his European tours (during the Napoleonic War!) makes one repeat with the author, "What a man!" During his great tours of the Continent he always carried with him his famous "portable chemical chest" and he was for ever making experiments. On one of these journeys he was involved in an altercation with Gay-Lussac over the discovery of a new substance which Davy eventually named *iodine*. His greatest practical discovery was perhaps the safety lamp for use in mines, but the author makes it quite clear that his most important discovery was a man—Michael Faraday, who became Davy's assistant at the Royal Institution.

Davy was also the friend of Coleridge, Southey and Sir Walter Scott, with whom he stayed on his visits to Scotland, where he enjoyed his sport and angling, and who, referring to Davy's rather unhappy marriage to a wealthy widow, remarked, "She has a temper, and he has a temper, and they fight like cat and dog."

This is a biography of a very human personality and a very great chemist—written by an author who has an unrivalled knowledge of the scientific background of the early 19th century.

### Plant Morphology

By A. W. Haupt (*New York and London, McGraw-Hill, 1953, 464 pp., 64s.*)

This is not, as the title would lead one to expect, an introduction to the general principles of plant morphology, but a systematic account of the structure and reproduction of the various sections of the vegetable kingdom, beginning with the Cyanophyceae and proceeding in ascending order. The traditions and usages of contemporary teaching create a large demand for such books, which naturally tend to follow an established convention. Their authors are faced with such immense problems of selection and compression that it would be manifestly unfair to cavil at particular omissions or to advert upon the occasional inevitable sacrifice of precision to brevity.

In fact, within the limits he has set himself, Professor Haupt has done very well. His account of the living cryptogams and gymnosperms is clear and accurate, with good and numerous illustrations, many of which are original. A modified type system is employed, and questions of phylogenetic speculation are handled with restraint. Extinct forms are mentioned in their appropriate places but are quite summarily treated. This is clearly a deliberate policy, for which the abundance of palaeobotanical texts is a sufficient justification. The work is clearly aimed at the post-Intermediate student, to whom it may be confidently recommended.

Unfortunately the chapter on angiosperms, amounting to a mere fifty pages, altogether fails to maintain the scholarly standards of the rest of the book. It comprises accounts of angiosperm anatomy and floral morphology, so very elementary as to be of little use to a student with any previous knowledge at all, a brief description of reproductive processes, and an outline of classification. The chapter contains many statements which are misleading and some which are flagrantly untrue.

For these faults the author is not solely to blame. The present system of university teaching and examining will tolerate almost any amount of ignorance regarding the morphology and classification of angiosperms, if only a student is thoroughly conversant with the reproductive idiosyncrasies of the more obscure ferns and liverworts. It must be admitted that under the prevailing conditions Professor Haupt could have done little service to his student readers by writing a longer or better account of the flowering plants. K. J. DORMER

### Engineering Electronics

By G. E. Happell and W. M. Hesselberth (*New York and London, McGraw-Hill, 1953, 496 pp., 60s.*)

Some weeks ago a writer in the *Manchester Guardian* compared American and British technical books, to the detriment of the

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home-produced article. The arrival of this book for review has provided a convenient opportunity for making a comparison, and it has therefore been read with more than usual care.

Books on electronics, particularly in the applications to industry, have been popular with American publishers and there are very few by British authors: possibly because electronic control is not used to the same universal extent as in America. On the other hand, there are several excellent books on electronic theory in this country, notably the one by P. Parker (Edward Arnold, 1950), and introductory texts by Yarwood and Lenihan.

It is difficult to find a comparable British text with the McGraw-Hill book reviewed here. It has been used at Purdue University for some years as an introductory course in electronics for engineering students and assumes a knowledge of general physics, mathematics up to calculus, and D.C. circuits. Probably the equivalent introduction to the subject in this country would be through a book on radio technology or through a series of shorter text-books dealing with one aspect, such as the radio valve and its circuits.

The present text-book covers a very wide field—from emission theory to solid-state electronics, and its adequacy as a book obviously depends on the authors' skill in compression. Here it is permissible to compare a section with the British equivalent. The chapter on 'Emission' occupies 18 pages; the chapter in Parker's *Electronics* on the same subject occupies 60 pages. All the salient points in the theory of emission are included in those 18 pages, but obviously Parker (who does not indulge in padding) is more thorough —his figures total 28 against 10—in fact decidedly in favour of the longer treatment. It might be argued, however, that the treatment of emission theory at length is too thorough for the average student who is not going to be an electronic physicist.

This comparision, sketchy as it is, provides a pointer to the relative attitudes of the British and American author. The British text-book usually strives for thoroughness, overlooking at times that the average student has no time for a complete study of the subject. The American text-book gives him just enough to "put him in the picture", knowing that in a few years' time another text will be needed to take him further.

In text-books as in other things, the British product is built to last. The American model serves the immediate purpose and can be discarded without difficulty when the time comes for a newer and later model to appear on the market.

G. PARR

**The Northern Sea Route**

By Terence Armstrong. Scott Polar Research Institute Special Publication Number 1. (*London, Cambridge University Press, 1952, 162 pp., 21s.*)

At a time when growing public attention is focused upon the increasingly important strategic regions and exploration of the Polar Regions, the publication of this detailed record of Soviet progress in Arctic Waters by the Research Institute is opportune. The author is to be congratulated on presenting a book, which, whilst it is so full of facts, vividly summarises the growth of the Northern Sea Route.

The English, as pioneers of most of the world's ocean trade routes, first ventured into these northern wastes in the early 16th century. After a barren three centuries they again ventured along these northern coasts in search of trade. It is notable that one of the pioneers of the western route to the Kara Sea was Captain Joseph Wiggins, a British seaman. The eastern route, which was developed slightly later, has been proved to be as difficult as the western sea way. Throughout the time when the early exploratory work was carried out the Tsarist governments showed varying degrees of indifference to the commercial exploitation of their northern territories. Later, after the Revolution, one of the main changes was to stimulate exploration and scientific research into the problems encountered in the establishment of coastal shipping movement from the Bahrents Sea to the Bering Strait. In dealing with this recent development the author very clearly presents the aspirations, motives and means by which Russian scientists have probed into Arctic waters with successes and failures which appear to have been variously rewarded. There is no doubt that the Russians have made much progress in these regions, particularly in the application of aids to the safe passage of shipping in the limited time the route is open each year by hydrographic surveys, and progress has evidently also been made in respect of forecasting weather and ice conditions. This wealth of information, mainly drawn from Russian sources, makes this book invaluable to all interested in Soviet scientific progress.

Not only does the author deal with the historical development of this sea way, but he also deals with allied problems—the construction of special ships, the supply of coal and fuel oil, air surveys of ice fields and mineral wealth for commercial exploitation. Furthermore, there are many important strategic points which are ably discussed. In the recent war the German raider *Komet* sailed from west to east into the Bering Straits in twenty-one days whilst at one time the *Admiral Scheer* operated in the Kara Sea.

For a guinea this book is excellent value, not only for the fine account of the development of the Northern Sea Route, but for the appendices and the excellent list of references. It is well illustrated and contains many maps and above all is an authentic record of progress by man against the elements.

F. A. HENSON

**Human Relations in Industry**

The joint committee on Human Relations set up by the DSIR and the Medical Research Council has published its first report—*Human Relations in Industry* (H.M.S.O., one shilling).

This committee was established in 1953 to advise on research into human relations in industry. Included in the report are details of research projects that have been approved and which are now going ahead.

Merely improving conditions of work has not been the first concern of the committee. The programme of work has been fully discussed with trade unionists and industrialists so that it should be as practical as possible. In every case the committee, under its chairman, Mr. A. B. Waring, managing director of Joseph Lucas Ltd., has tried to take a broad view of productivity needs because, it believes, "greater human satisfaction in work is both compatible with and essential to increased efficiency and productivity".

The main job of the committee during the year has been the building up of a research programme. Seventy-eight projects were considered by the committee and twelve of them have already been approved, their estimated cost being about £89,000.

One project, on the effect of incentive payment schemes on productivity, is being carried out by Birmingham University. The experience of factories that have introduced incentive payments will be assembled and analysed, account being taken of trade union attitudes and experience.

Edinburgh University is to carry out two researches. In previous work this university had found that there was, in some firms, friction between inspection and production departments, which caused inefficiency. The work now in progress is directed to finding out how the inspection process can best be organised to avoid this. The other project is on the problem of adjustment to technological change, and it will be done with the co-operation of several Scottish firms which have recently begun to develop electronic equipment.

Factors helping or slowing down technological change are given considerable importance in the committee's programme. Liverpool University is studying the way in which new production methods and techniques can be absorbed without raising human problems. The research began at a big steel firm in this country and the Liverpool team is co-operating with researchers in Holland, Germany, Belgium and other countries in order to compare results with them.

The Acton Society Trust will carry out some research in this field. It will investigate the effect of promotion policies and practices on efficiency and morale in industry. Comparisons will be made between different promotion schemes in large-scale industry.

The committee is particularly anxious that the results of the research should be known and acted upon in industry. How to bring this about is an urgent problem, and it is considering various ways and means, including 'industrial' versions of research reports written with the needs of industry especially in mind.

All inquiries concerning this report (other than applications for copies, which are obtainable through H.M. Stationery Office or—on order—through booksellers) should be addressed to: J. R. Gass, Esq., DSIR, Charles House, 5–11 Regent Street, London, S.W.1. WHitehall 9788, Ext. 56.

# *The British Journal for the Philosophy of Science*

Volume V No. 17 May 1954

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EXPERIMENTAL OFFICERS AND ASSISTANT EXPERIMENTAL OFFICERS in various Government Departments. The Civil Service Commissioners invite applications for pensionable posts. Applications may be accepted up to 31 December, 1954, but forms should be returned as soon as possible as an earlier closing date may be announced either for the competition as a whole or in one or more subjects. Interview Boards will sit at frequent intervals.

The posts are divided between following main groups and subjects: (*a*) Mathematical and Physical Sciences, (*b*) Chemistry and Metallurgy, (*c*) Biological Sciences, (*d*) Engineering subjects and (*e*) Miscellaneous (including e.g. Geology, Library and Technical Information Services).

*Age limits:* For Experimental Officers, at least 26 and under 31 on 31 December, 1954; for Assistant Experimental Officers at least 18 and under 28 on 31 December, 1954. Extension for regular service in H.M. Forces.

Candidates must have at least one of a number of specified qualifications. Examples are Higher School Certificate, General Certificate of Education, Scottish Leaving Certificate, Scottish Universities Preliminary Examination, Northern Ireland Senior Certificate (all in appropriate subjects and at appropriate levels), Higher National Certificate, University degree. Candidates taking their examinations in 1954 may be admitted. Candidates without such qualifications may be admitted exceptionally on evidence of suitable experience. In general a higher standard of qualification will be looked for in the older candidates than in the younger ones.

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Further particulars and application forms from Civil Service Commission, Scientific Branch, 30 Old Burlington Street, London, W.1, quoting No. S.94-95 54.

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Age at least 17½ and under 26 years of age on 1 January, 1954, with extension for regular service in H.M. Forces but candidates over 26 with specialised experience may be admitted.

Candidates must produce evidence of having reached a prescribed standard of education, particularly in a science or mathematical subject. At least two years' experience in the duties of the class gained by service in a Government Department or other civilian scientific establishment or in technical branches of the Forces is essential in one of the following groups of scientific subjects:

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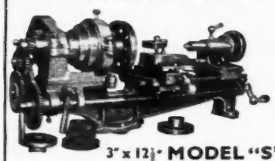

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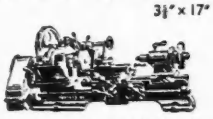

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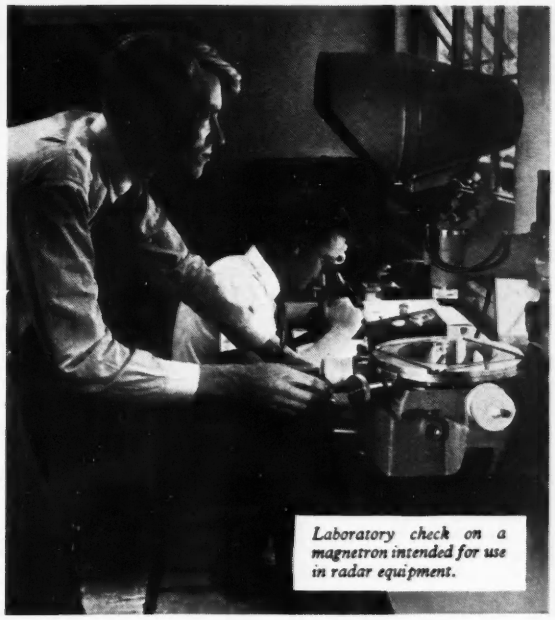

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